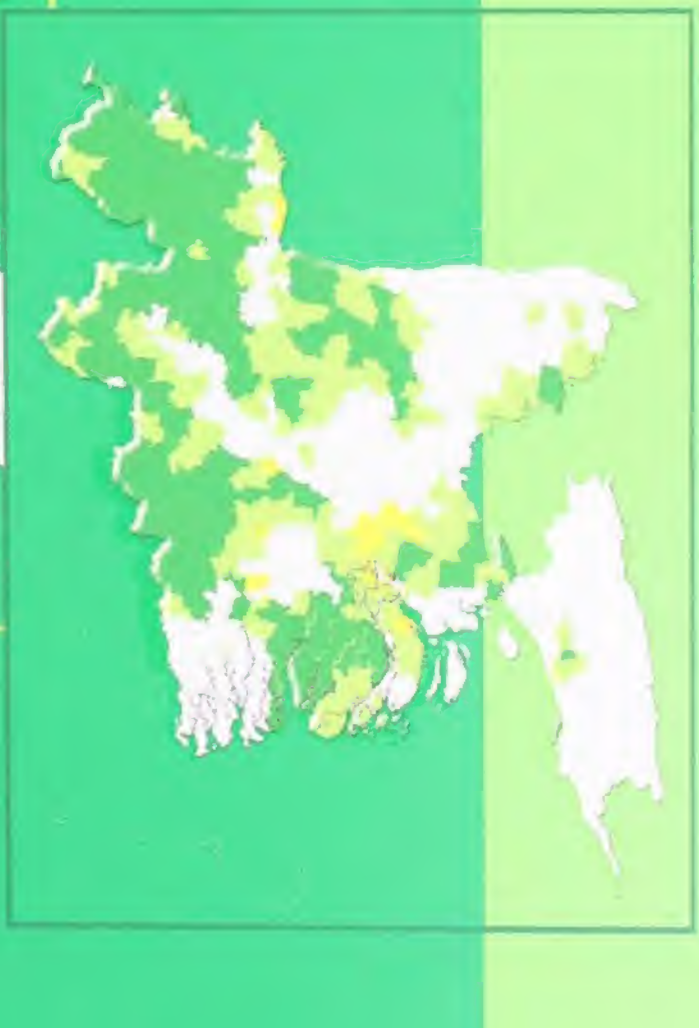
Land Suitability Assessment and Crop Zoning of Bangladesh



Bangladesh Agricultural Research Council

Land Suitability Assessment and Crop Zoning of Bangladesh

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بسم الله الرحمن الرحيم

Minister
Ministry of Agriculture
Government of the Peoples
Republic of Bangladesh

FOREWORD

Agriculture is a major source of livelihood of majority people and a driving force for national growth and development in Bangladesh. The primary concern of the government is to ensure food security and alleviate poverty through rapid and sustained growth and development of agriculture. But the productivity and the production resources, especially the land, water and genetic resources are rapidly shrinking and degrading. In the years ahead agriculture will be required to produce more diversified food with greater shares of cereals, vegetables, fruits, meat, fish and milk. This can only be achieved through well planned intensification programme of use of land, water and labour along with improvement of food security and rural livelihood.

Agro-climatic condition and fertile land of the country are favourable for growing different kinds of crops. But the country is at present facing the challenges of increased food production for growing population under stress of decreasing land resources.

In this context, I am happy to know that BARC has taken an initiative to prepare Crop Zoning Map of Bangladesh based on soil and agro-climatic conditions. The purpose of the crop zoning is better utilization of land and water resources for maximization of crop production with lesser cost. I congratulate BARC for undertaking the pains for such an excellent work of preparing the crop zone map based on land suitability for a particular crop in a given area. I also thank the authors for the contributions and efforts that have made the crop zoning maps possible. It will provide guidelines to the farmers to select the right crop in a right environment. I strongly believe that the use of crop zone maps will bring immense benefit to the farmers in reducing cost of the cultivation and maximizing production. It will help the policy maker, planners and think tankers prepare the future policy guidelines and strategy in agriculture.

Matia Chowdhury

Matia Chowdhury, MP
Minister of Agriculture
Government of the People's Republic of Bangladesh

PREFACE

Agriculture in Bangladesh contributes greatly to improve food security, employment and livelihood. But the net cultivable area (NCA) of agriculture is shrinking everyday due to non-agricultural use. During 1971 the NCA was 8.43 million hectares. It has gone down to 7.79 million hectares. On the other hand, the cropping intensity has increased significantly because of high demand for food production. Cereal production has increased from about 10 million tonnes in 1970 to about 30 million tones at present. As a consequence more pressure is exerted on the land and water resources and their sustainability. Land degradation is a serious concern. Over-exploitation of groundwater in the northwestern part of the country is causing problems like inadequate recharge and draw-down effect. However, the Government of Bangladesh is committed to increasing food security through agricultural development of the country.

The Ministry of Agriculture includes plans to modernize the agriculture sector through enhancing productivity, strengthening value chains, and improving quality standards. The government is providing subsidies in inputs like fertilizer and electricity/diesel for irrigation pumps.

The Hon'ble Minister for Agriculture of Bangladesh Begum Matia Chowdhury has directed the Bangladesh Agricultural Research Council to prepare a report on land suitability and Crop Zoning so that agricultural land in different parts of the country can be utilized and competition for resources like water and land can be rationalized.

I thank the authors Dr. Sk. Ghulam Hussain, Dr. M Khalequzzaman A Chowdhury and M. Abeed Hossain Chowdhury of BARC for their initiatives and endeavour for carrying out crop suitability and zoning studies and preparing this document. The maps of land suitability and crop zones identified for the selected crops and the strategies and recommendations suggested would be helpful for the policy planners, researchers, development and extension workers for judicial use of scarce natural resources and optimize land use. It is hoped that this publication will be useful for all stakeholders.

Finally, I would like to acknowledge the support provided by the Experts and Scientists of the NARS and DAE who took part in preparation of this important document and sharing of knowledge and wisdom in characterizing land, soil, climate for different crops.

I hope that this publication would be of much help to the policy planners, researchers, and development and extension workers in their future endeavors. It is also hoped that implementation of zoning concept will have positive impact on food security and livelihood improvement of the rural people.

Dr. Wais Kabir
Executive Chairman, BARC

ACKNOWLEDGEMENT

In the Annual Development Programme (ADP) meeting held on 29 July 2010, presided over by the Hon'ble Minister for Agriculture, Begum Matia Chowdhury, it was decided that crop zoning map would be prepared with technological and management support. So that the agricultural land in different parts of the country can be appropriately utilized to its full potential and competition for resources like water and land can be rationalized.

To implement the decision, BARC was given the responsibility to prepare the document. An 11-member committee was formed by the Executive Chairman of the Bangladesh Agricultural Research Council vide memo No. PS/BARC27/2009. The following were the members of the committee:

1. Executive Chairman, BARC, Dhaka	Convenor
2. Director (Field Services) DAE, Dhaka	Member
3. Member-Director (Planning and Evaluation), BARC, Dhaka	Member
4. Member-Director (Crops), BARC, Dhaka	Member
5. Director (Research), BARI, Gazipur	Member
6. Director (Research), BRRI, Gazipur	Member
7. Director (Research), BINA, Mymenshing	Member
8. BADC Representative in the rank of General Manager	Member
9. Director (Computer & GIS), BARC, Dhaka	Member
10. SRDI Representative (Not below the rank of PSO)	Member
11. Chief Scientific Officer (Crops), BARC	Member-Secretary

Several meetings were held with representatives from most of the organizations to finalize the crops to be included and to characterize edaphic and agroclimatic limitation for the selected crops.

A sub-committee was formed by the Executive Chairman, BARC, Convenor of the committee, with the authors of this document as members.

Sincere appreciation is extended to all the NARS scientists and experts for sharing their knowledge and wisdom in characterizing land, soil, and climate suitability for different crops.

The thoughtful scientific judgment and contributions of Mr. Mainul Ahsan, Director, SRDI, Dr. Md. Badirul Islam, CSO, OFRD, BARI, Dr. Md. Akhtar Hossain Khan, CSO, BRRI, and Mr. Anil Chandra Sarkar, Additional Director, DAE for formulation of the crop specific edaphic and climatic limitations is highly appreciated. Without their help it would have not been possible to complete the crop zoning exercise.

Special thanks are given to Dr. Abul Kalam Azad, Chief Scientific Officer (Crops), BARC for rendering assistance as the Member-Secretary of the committee for preparation of the document on Crop Zoning.

The authors would also like to thank Dr. Wais Kabir, Executive Chairman, BARC for his valuable advice during the preparation of this document and for giving his precious time in going through the manuscript. Special thanks to Dr. Shahjahan, Ex-Director (R&D), BSFIC for providing valuable suggestions and corrections on the manuscript.

Lastly, we sincerely thank the Committee Members for their contributions and hard labour for preparation of this document.

Authors

ACRONYMS & ABBREVIATIONS

AEZ	Agro-ecological Zones
BARC	Bangladesh Agricultural Research Council
BMD	Bangladesh Meteorological Department
CEC	Cation Exchange Capacities
DAE	Department of Agriculture Extension
DAS	Days After Sowing
DEM	Digital elevation model
DTW	Deep tube-well
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
HYV	High Yielding Variety
IPCC	Intergovernmental Panel on Climate Change
LRI	Land Resources Inventory
LRIS	Land Resources Inventory System
LS	Marginally Suitable
LUT	Land Utilization Table
Mha	Million hectare
MoA	Ministry of Agriculture
MS	Moderately Suitable
Mt	Million tonne
NARS	National Agricultural Research System
NCA	Net Cropped Area/Net Cultivable Area
NS	Not Suitable
PET	Potential Evapotranspiration
S	Suitable
SRDI	Soil Resources Development Institute
STW	Shallow tube-well
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
VS	Very Suitable

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1. Introduction

The rapidly growing population exerts considerable pressure on scarce natural resources of the country. According to the census of March 15, 2011 the population was 142.319 million which is 2.04% of the world population. Bangladesh is the twelfth most densely populated country of the world with a density of 988 person km^{-2}. Rapid increase of population is the major problem of the country. Average annual population growth rate (2001-11) is about 1.34 %, which indicates addition of about two million new mouths every year. The projected population for the 2020, 2030, 2040, and 2050 would be 169.54, 189.85, 205.13, and 217.54 million respectively and the estimated food, especially rice and wheat, requirements would be 25.943, 27.632 and 32.377 million tonnes (MoA, 2007). There is an urgent need for more efficient and sustainable agricultural production systems in this country.

Agriculture is the main source of food for human and prime source of raw materials for industries. It is greatly dependent on environmental conditions. Growth and development of plants are controlled by the environments - climate and soil. Therefore, the environmental conditions should be adequately assessed in any regional development plan. The first and most decisive step in any planning should be the identification of areas where the soil and climate are suitable for a given crop. According to Pereira (1983), crop zoning is the art of choosing the right crop for the right environment. But even for the suitable areas the success or failure of a crop depends on the economic and social factors of the area that grows the crop.

Sivakumar and Valentin, (1997) suggest that this should be based on an initial assessment of the bio-physical potential of natural resources, which can vary greatly. The agroecological zoning approach presents a useful preliminary evaluation of this potential, and ensures that representation is maintained at an appropriate biogeographic scale for regional development planning. A concept introduced by the FAO, for assessing the crop production potential, where length of the growing period is very useful as it describes an area within which rainfall and temperature conditions are suitable for crop growth for a given number of days in the year. These data, combined with the information on soils and known requirements of different crops, can be used to assess the potential crop productivity.

Crop zoning can be conceptualized in the context of optimizing crop production through judicious use of land and water resources. Prevent degradation of resources of the environment, plan for optimum use and conserve for future.

Usually, land use planning is done for (1) resource conservation and environment protection (2) resource management and (3) urban and industrial use. The purpose of crop zoning is to make best and sustainable use of scarce land and water resources for food production.

1.1. Scarcity of Land Resources

The total area of the country is about 14.84 Mha of which 3.60 Mha (24.26% of total area) is not available for agriculture. This land is occupied by scattered homesteads, urban centers, industries, educational institutions and inhabited lands. At the time of independence during 1971 the net cropped area of the country was 8.24 Mha and reached 8.85 Mha in 1987 with a cropping intensity of 150.73%. Although the net cultivated area (NCA) declined to 7.94 Mha in 2009, the total cropped area increased to 14.41 Mha. This increase is attributed to the increase in double and triple cropped areas. During the last decade on annual average decline rate in NCA is 0.735% which is more than 57.8 thousand hectares per year.

A large areas that were not available for cultivation or classified as cultivable waste (0.23 Mha). Most of these lands were barren, with very limited vegetation. Currently, the forests occupy more than 17% of the land area. However, in reality this may not be the case. Huda and Roy (2000), reported that "although forests are officially stated to occupy more than 15% of the land area of Bangladesh, the actual tree-covered area is reported to have fallen to only 6% at present." Of the arable land area (8.24 Mha), 28.40% is single cropped, 47.57% double cropped, 15.53% triple cropped and 8.50% is cultivable waste and currently fallow land (Table 1). The cropping intensity has now reached 185.89%.

Table 1. Land utilization statistics

Year: 2008-09	Area (Mha)	% Total Area	% Arable Land (8.24 Mha)
Total area	14.84	100	
Not available for cultivation	3.60	24.26	
Forest	2.60	17.52	
Cultivable waste	0.23	1.55	2.79
Current fallow	0.47	3.17	5.70
Single cropped area	2.34	15.77	28.40
Double cropped area	3.92	26.45	47.57
Triple cropped area	1.28	8.62	15.53
Net cropped area	7.94	53.50	
Total cropped area	14.41	97.10	

Source: BBS, 2011

1.2. Scarcity of Water Resources

During 1999-2009 the annual average growth of irrigated areas was 4.74%. Currently, total minor irrigation command area is 6.36 Mha. More and more areas are being irrigated with groundwater, as it is the major source of irrigation in Bangladesh. Groundwater is abstracted through deep tube-wells (DTW) and shallow tube-wells (STW) while, surface water is lifted by low lift pumps and traditional methods. Of the national irrigation coverage, groundwater and surface

water covers 77% and 23% percent respectively. A summary of irrigation with surface and groundwater by different modes during 2008-09 is presented in Table 2. About 70.0% of the total irrigated areas are covered by Boro rice grown during January-May. The source of irrigation is groundwater (54%) and surface water (16%). About 9.02%, 5.24%, and 5.25% of the total irrigated areas are covered by aman rice, wheat, and potato respectively. Rest of the crops including vegetables, sugarcane and other crops cover only about 11% of the irrigated area.

Table 2. Areas under different crops irrigated by various means

Name of crops	Irrigation with groundwater (Mha)				Irrigation with surface water (Mha)			Total areas under different crops (Mha)
	Deep tube-well	Shallow tube-well	Hand Tube-well	Total	Power pump	Traditional	Total	
Aman	0.0817	0.3590	0.0020	0.4427	0.0987	0.0320	0.1307	0.5735
Boro	0.6354	2.7766	0.0146	3.4265	0.7633	0.2473	1.0105	4.4371
Wheat	0.0478	0.2084	0.0012	0.2574	0.0575	0.0182	0.0757	0.3331
Sugarcane	0.0073	0.0312	0.0000	0.0384	0.0085	0.0028	0.0113	0.0498
Cotton	0.0008	0.0032	0.0000	0.0040	0.0008	0.0004	0.0012	0.0053
Potato	0.0478	0.2088	0.0012	0.2578	0.0575	0.0186	0.0761	0.3339
Vegetables	0.0356	0.1550	0.0008	0.1914	0.0425	0.0138	0.0563	0.2477
Others	0.0538	0.2351	0.0012	0.2902	0.0648	0.0210	0.0858	0.3760
Total area under different means	0.9102	3.9773	0.0210	4.9085	1.0935	0.3541	1.4476	6.3561

Source: BBS, 2010

At present, the amount of pumping out of groundwater from the aquifers greatly exceeds the amount of recharge resulting in lowering of groundwater levels at alarming rates. Groundwater is available at comparatively shallow depths during August-October (at the end of the rainy season) and at deep depth during April-May, i.e., at the end of the dry season (Ali, 2010).

Irrigation pumps can not draw water properly from underground reservoir due to inadequate information about aquifer characteristics and improper fielding of shallow tubewells (STW) and deep tube-wells (DTW). Jaim (1993) reported that in many areas of northwest Bangladesh excessive number of DTWs have already been installed where only STWs can successfully operate. Installation of excessive number of DTWs and STWs in some areas is also causing inefficiency in terms of coverage. It is feared that over-exploitation of groundwater through rapid expansion of STWs may cause drawdown effect in the near future in the northern region of the country. During dry season, in the drought-prone areas, water tables are lowered considerably, making lifting of groundwater by STWs impossible. Khan (1988) reported that abstraction of groundwater might cause a number of undesirable environmental consequences such as decline in groundwater level, salinity or water quality problems. Therefore, the current estimates should be validated at field level. If the results are satisfactory, only then should these values be used in making groundwater extraction plans. A zoning policy may be needed

and enforced in future to protect the interests of the farmers involved in various modes of water extraction. Monitoring of groundwater utilization by government agencies should continue so as to avoid over-extraction and quality deterioration (Karim and Hussain, 2003).

In Bangladesh, additional agricultural output will have to come from multiple cropping which requires, among other things (*inter alia*), increased irrigation. The selection of the optimal technology is important not only because of shortage of the country's overall resources but also of inadequate supply of other much-needed agricultural inputs such as fertilizers, pesticide and quality seeds which also require considerable additional investment. There is potential for high returns from Bangladesh's agriculture sector through more efficient use of all resources.

Surface water irrigation is also important in Bangladesh but the present study is limited to groundwater irrigation technologies for a number of reasons. Ground water and surface water schemes are difficult to compare. They are now treated as alternative choices in most instances than pumping up water from below the ground. It would be difficult to obtain the very detailed information required for inclusion of large surface water projects. Finally, as a matter of policy relevance, groundwater technology is the portion of the irrigation programme in Bangladesh that is most likely to be expanded in future (Hannah, 1978). By now, probably the potential for groundwater has been reached, and not much scope left for its expansion.

1.3. Climatic Resources

The climate of Bangladesh is generally sub-tropical in the north to hot humid in the south. Southwest monsoon influences the climate during June to October. During winter the climate is controlled by the northeast monsoon from November to March. The summer is hot and humid and the winter is mild.

1.3.1. Temperature

Figures 1 and 2 summarize the long-term monthly average of maximum and minimum temperature ranges of the country. The highest monthly average maximum temperature of 36.3° C is recorded in April and the lowest monthly average minimum temperature of 9.5° C is recorded in January. The maximum and minimum temperatures varied within the range of 1.6 to 5.5° C and 1.4 to 5.6° C all over the country.

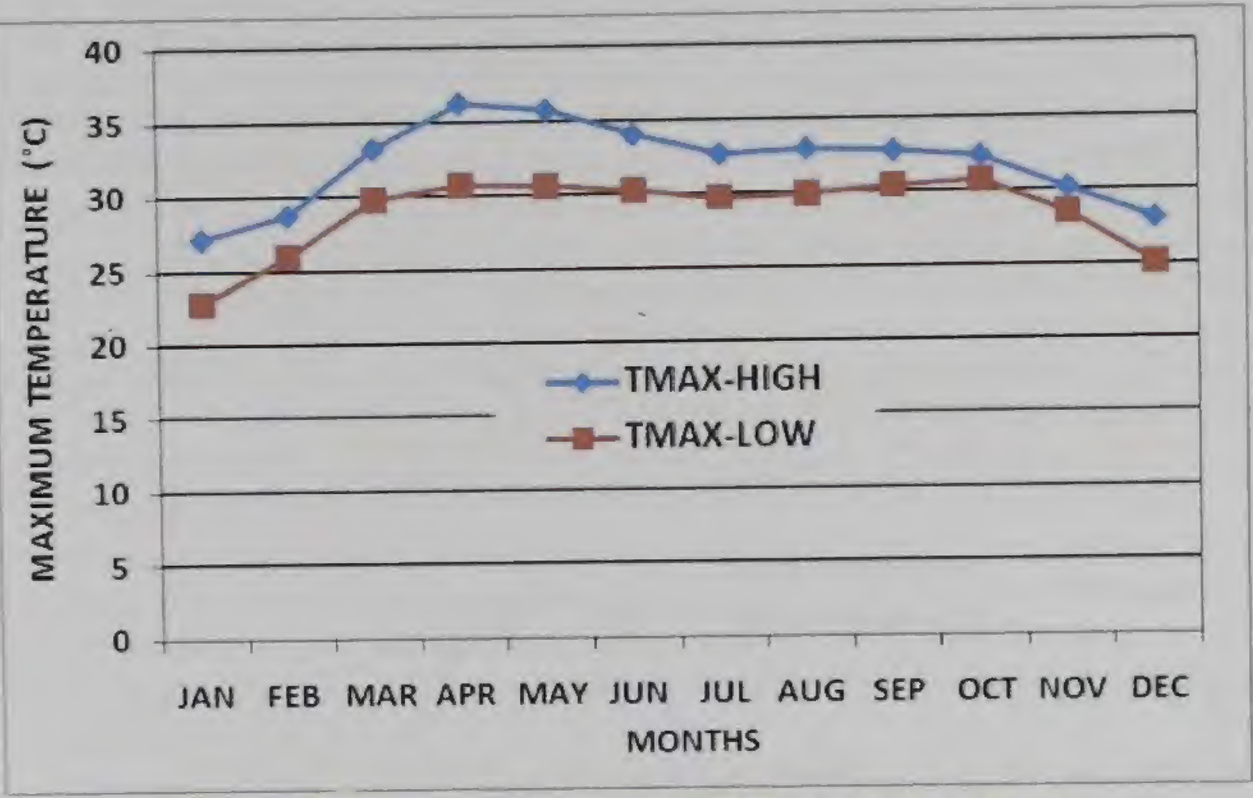

Figure 1. Maximum Temperature (Long-term Average)

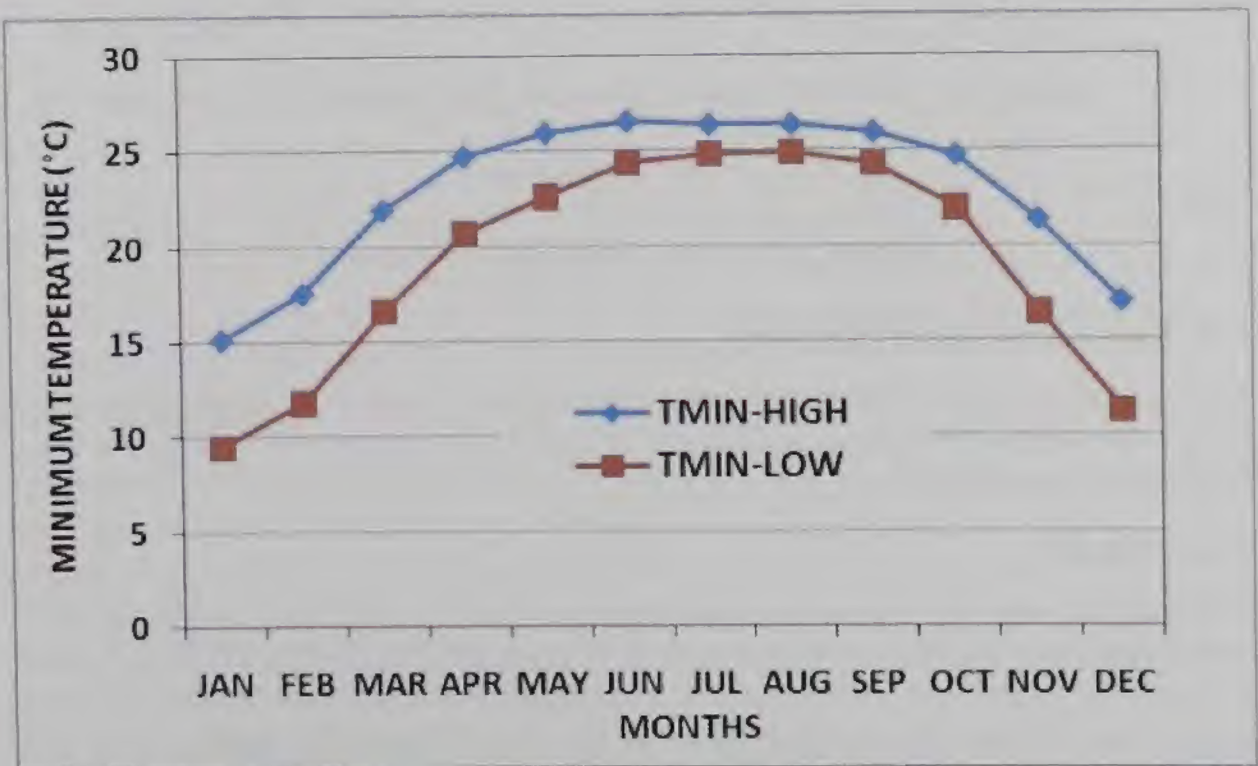

Figure 2. Minimum Temperature (Long-term Average)

1.3.2. Rainfall

Annual rainfall ranges from <1500 mm in the dry northwest region to over 5000 mm in the wet northeast region of Bangladesh. These values are not alarming for a nation if the distribution is even throughout the year. It becomes hazardous when the distribution is erratic and uneven. In one hand, too much in a single slot creates floods and on the other, too little causes drought. About ninety percent of the precipitation generally occurs during the monsoon (June to September); but the distribution within these four months varies greatly. It is evident from Figure 3 that large temporal variations exist within and among the seasons in mean rainfall. Spatially, >4000mm of rainfall occur in Sylhet and <1600 mm in Chuadanga. The country average is 2428 mm.

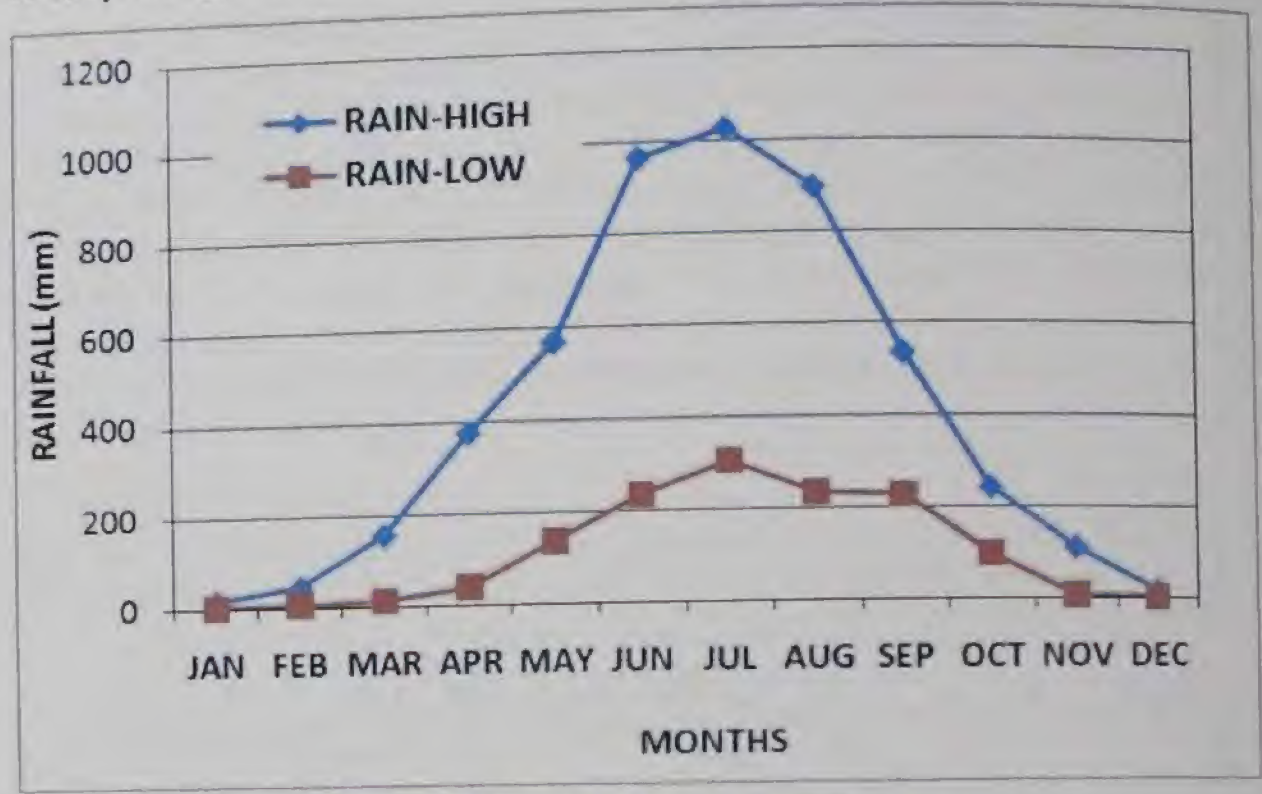

Figure 3. Rainfall (Long-term Average)

1.4. Environmental Hazards

The country is vulnerable to many environmental hazards, including frequent floods, droughts, cyclones, and storm surges that damage life, property, and agricultural production.

1.4.1. Floods

Flooding during the monsoon season from June to October is common. In Bangladesh, about 80% of the land area is flood-prone. Normally, 22% of the land is inundated every year. Normally, the flooding depth varies from 30 cm to 2.5 m. More than 80 percent of the cultivable land is affected by floods, droughts, cyclones, and tidal-surges. Among these, floods are the most detrimental to the social and economic well being of the country.

In Bangladesh, floods of the following types are generally encountered (UNDP, 1988):

Flash floods in the eastern and northern rivers are characterized by a sharp rise in water levels followed by relatively rapid recession a few days later; they are often associated with high velocities that damage crop and property.

Floods due to high-intensity rainfalls are caused by rainfall intensities and long rainfall durations in the monsoon season which generate water volumes in excess of local drainage capacity.

Monsoon floods from the major rivers (the Ganges, the Brahmaputra and the Meghna) occur when the rivers and tributaries overflow its banks. These rivers generally rise slowly over a period of 10 to 20 days, or more. But extensive damage is caused particularly when the three major rivers rise simultaneously.

Floods due to storm surges and tidal waves occur in the coastal areas with large estuaries, extensive tidal flats, and low-lying islands. In the event of storm surges caused by tropical cyclones inflict extensive damage to life and property. Cyclones appear during the pre- and post-monsoon periods (April-May and October-November, respectively).

Flooding due to high-intensity rainfall and overflow of rivers is very common in Bangladesh. These floods affect the rice crop at different growth stages. Bangladesh floods can be categorized according to the extent of damage they cause. When more than 35 percent of the country is inundated, the damage can be catastrophic.

Floods in Bangladesh have been categorized into early-flooding which occurs during mid-June to mid-July, normal-flooding which occurs during mid-August to mid-September and late-flooding which takes place between mid-September and late October. Among these, early-flooding is the most damaging even though its areal extent is small compared to the other categories because people are unprepared for them. The extent of normal-flooding is very large, but the amount of damage is small. Late-flooding causes moderate damage and the extent is small. The nature and causes of floods are varied; therefore, the magnitude of damage varies with timing, location and intensity.

1.4.2. Drought

Like floods, occurrence of droughts is also an annual event. During the kharif and rabi seasons 2.20 million hectares and 1.2 million hectares, respectively are affected by droughts of varying intensities. Until now, ten severe droughts and seven moderate droughts occurred in Bangladesh. A severe drought could be as dangerous as a major flood or cyclone. Foodgrain production could be drastically reduced as a consequence of a drought.

Highland and Medium highlands are most suitable for transplanted HYV aman rice cultivation. If early drought occurs then transplanting of aman rice is delayed. Consequently the harvesting of the crop is also delayed. As a result the farmers can

not plant the rabi crop. Hence the land most often remains fallow after T. Aman. Early drought retards tillering and vegetative growth which in turn reduces the achievable yield of the crop. Maximum susceptibility factor of T. Aman is during heading, panicle initiation and milking periods. Thus, drought in the later growth period of T. Aman may cause very large yield reduction.

During rabi growing period, the rate of evapotranspiration exceeds mean monthly rainfall. Rainfall is erratic during pre-kharif period. Land type and soil texture are also other important determinants for soil moisture situation. In light textured soil with high infiltration rate, rabi crops are more vulnerable to moisture stress. Rabi crops frequently suffer from moisture stresses from mid-stages of growth.

1.4.3. Tropical Cyclone

Tropical cyclones are important features of the weather and climate of south Asia. The major cyclogenesis of this region exists in the northern Indian Ocean, which particularly affects Bangladesh and parts of India. IPCC (2001) indicates, it is likely (60-90% chance) that there would be an increase in tropical cyclone peak wind over some areas of this region. In Bangladesh cyclone occur during the period from mid-April to mid-November. Figure 4 presents a schematic calendar to illustrate the occurrence of variour hazards and possible crops that might be affected.

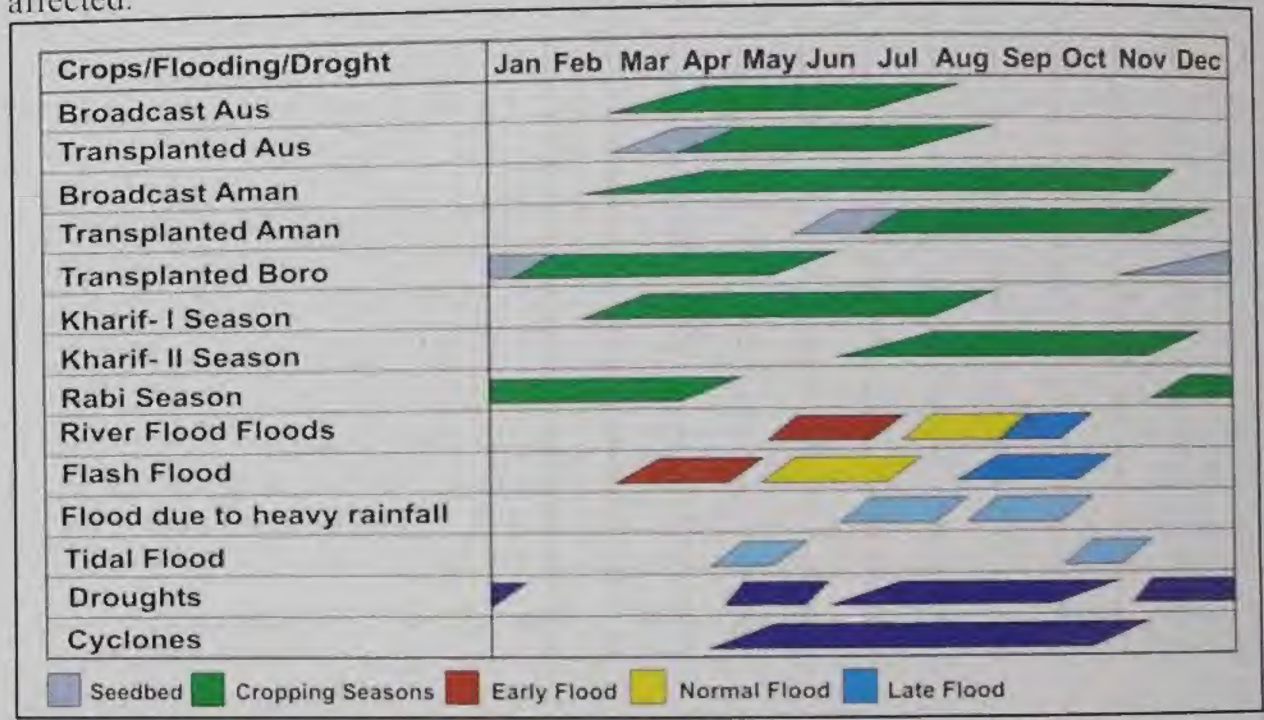

Figure 4. Crop and Hazards Calendar of Bangladesh

Source: Hussain, 1995 (Modified).

1.4.4. Water Logging

The growth of most crops is affected when the high water table causes the root zone become wetter than the field capacity. The excess water due to water logging and the resulting wet root zone can lead to some serious diseases in the root system and the stem. Working on too wet soil can destroy its structure, restrict root growth and affect drainage further.

The chemistry and microbiology of waterlogged soils is altered due to the absence of oxygen. This can result in changes and affect the availability of many nutrients. For example, nitrogen can undergo denitrification more readily and be lost to the atmosphere as a gas. The anaerobic (reducing) environment may bring changes in the available metals and other cations that can cause deficiencies or toxicities. Sulfide, ferrous and manganese ions may accumulate in waterlogged soils. Tolerances to water logging and a high water table vary with crops as well as with soil texture. Some crops, such as rice and sugarcane, are largely tolerant but crops like chili and onion are very much susceptible to water logging.

1.4.5. Soil and Water Salinity

Bangladesh has vast coastal areas covering about 20 per cent of the country with 710 km coastline along the Bay of Bengal. More than 30% of the cultivable land is in the coastal area. Out of 2.86 Mha of coastal and offshore lands about 1.056 Mha of lands are affected by different degrees of salinity. Of the 151 Upazilas (sub-districts) in 19 coastal districts, 93 Upazilas under 18 districts are affected by salinity.

As the cropping intensity and crop yields in the coastal zones are well below the country average, the contribution to agriculture sector is not proportional to its land mass. The reason behind this is unfavourable agroecological conditions of the region. These include coastal flooding in the monsoon and higher levels of soil salinity in the winter. The higher water salinity in winter reduces its potential for irrigation.

Crop yields decrease linearly with increasing salt levels above a given threshold level. Threshold level varies according to the tolerance of the crop. Yield decreases in absence of boron are mainly due to difficulties of the crop in taking up water due to the high concentration of salt in the soil solution. In high salt soils, often crops present a droughty or dry appearance due to osmotic potential related stress.

1.5. Climate Change

Climate change is no longer a propaganda, it is a reality. It is showing its effects through increasingly erratic behaviour. Climate change will exacerbate the environmental hazards as mentioned by IPCC (AR4, 2007). The Fourth Assessment Report of the IPCC (2007) considers agriculture and water as the most susceptible sectors to climate change-induced effects in Asia. Agriculture is one of the most vulnerable systems to be affected by climate change in the South Asian region. Agricultural productivity in this region is likely to suffer severe losses because of high temperature, severe drought, floods, and soil degradation.

According to the IPCC, Bangladesh will be one of the worst victims of climate change. Sea level will be increased due to rise in temperature and the frequency of cyclone-storms will also be increased. As a result, food security will be in jeopardy and different types of natural calamities will put lives at risk. On top of these, high population density will make the problem more serious.

The people of Bangladesh have been adapting to the risks of floods, droughts and cyclones for centuries. Heavy reliance of rural people on agriculture and natural resources increases their vulnerability to climate change. Therefore, supporting rural and urban communities to strengthen their resilience and adaptation to climate change will remain a high priority in coming decades. Disaster management, climate change and other related issues in agriculture are cross-cutting in nature. All the sub-sectors of agriculture are vulnerable to natural hazards, shocks and stresses. Although, all the sub-sectors might not be affected equally, but it is likely that some would be more susceptible.

1.6. Crops Selected

The country is blessed with a climate which is favorable for the cultivation of a wide range of both tropical and temperate crops. Rice is the dominant crop grown in three distinct rice growing seasons namely, `Aus' (April to August), `Aman' (July to November), and `Boro' (December to May). In Bangladesh, it is cultivated on 11.35 Mha of land to produce 45.69 Mt paddy equivalent to 31.98 Mt milled rice. The people of Bangladesh consume about 6.50% of the global consumption. There are also three growing seasons for other crops in the country. They are: `rabi' (dry season), `kharif I' (transition between dry and wet seasons) and `kharif II' (wet season). The extent and production of major crops grown in the country are presented in Table 3.

Wheat, oilseed crops, most pulses, potato, etc. are grown as rabi crops. Jute is grown as kharif-I crop and maize, chili, groundnut, mungbean, etc. are grown in both rabi and kharif-I. A calendar of selected crops depicts the sowing/ transplanting and harvesting schedules (Figure 5). The crops were selected for suitability assessment based on their importance.

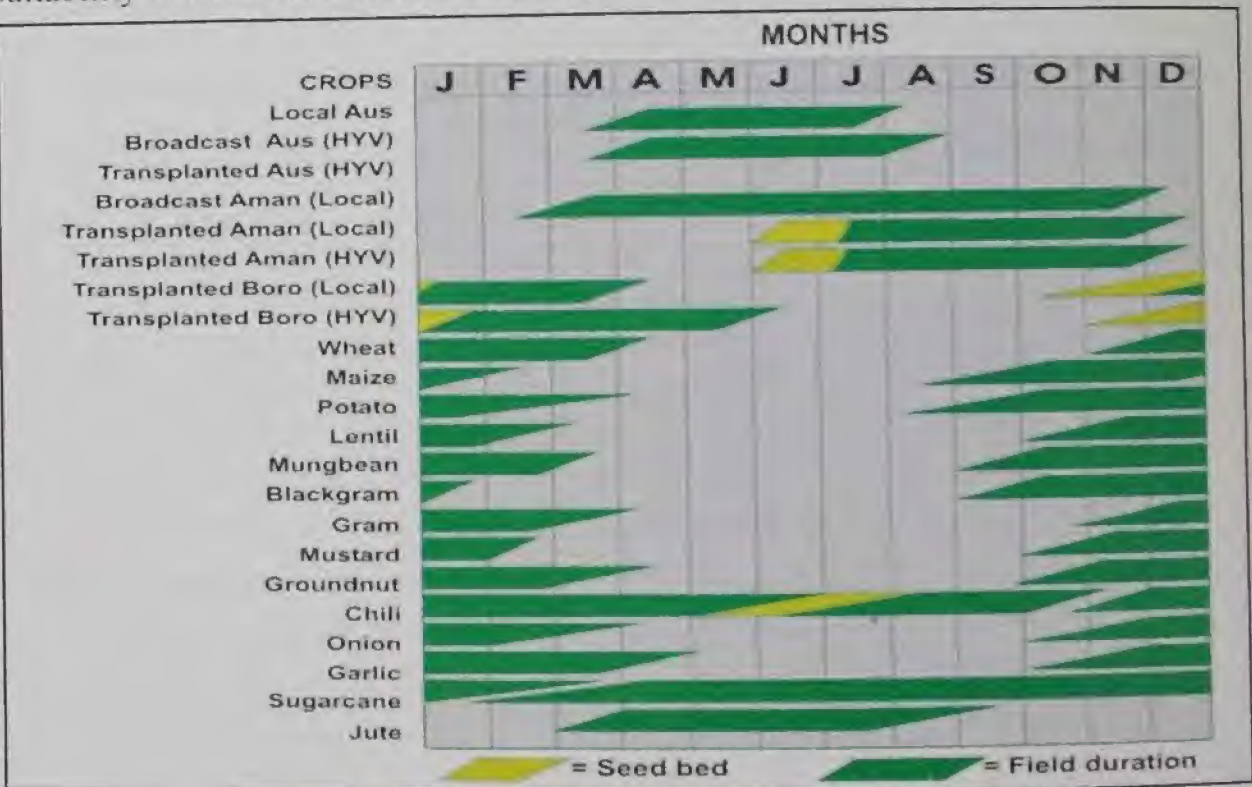

Figure 5. Calendar of Selected Crops

Table 3. Areas and production of major crops of Bangladesh (2009-2010)

Crop	Area (Mha)	Production (Mt)*
Rice *(Oryza sativa)*		
Total Aus	**0.984**	**1.709**
Aus (Local)	0.337	0.393
Aus (HYV)	0.647	1.316
Total Aman	**5.663**	**12.207**
Local Transplant (L.T.) Aman	1.414	2.237
Aman HYV	3.773	9.404
B. Aman	0.476	0.567
Total Boro	**4.707**	**18.059**
Local Boro	0.107	0.215
HYV Boro	3.917	14.622
Boro Hybrid	0.686	3.222
Total Rice	**11.354**	**31.975**
Wheat *(Triticum aestivum)*	0.376	0.901
Maize *(Zea mays* L.*)*	0.152	0.887
Potato *(Solanum tuberosum)*	0.435	7.930
Gram/Chickpea *(Cicer arietinum)*	0.007	0.006
Lentil *(Lens culinaris)*	0.077	0.071
Mungbean *(Vigna radiata)*	0.023	0.020
Blackgram *(Vigna phaseolus)*	0.032	0.028
Groundnut *(Arachis hypogaea)*	0.034	0.053
Rape & Mustard *(Brassica campestris/ Brassica juncea)*	0.242	0.222
Chillies *(Capsicum annuum)*	0.087	0.109
Onion *(Allium cepa)*	0.118	0.872
Garlic *(Allium sativum* L.*)*	0.037	0.164
Sugarcane (*Saccharum officinarum*)	0.118	4.491
Jute *(Corchorus oliterius/Chorcorus capsularis)**	0.416	0.916

Source: BBS. 2010. Summary of Crop Statistics, * (1 bale = 180 kg)

Rice production in the country is near to its requirement. But only potato is produced more than its requirement. Other crop productions are deficient in the country. The country spends a huge amount of foreign currency in importing sugar, pulses, oilseeds and spices every year. In order to reduce import dependency by increasing domestic production, the government implemented different action

plans for pulses, oilseeds and spices. The deficiency of some crops can be minimized through increasing production in a suitable land with a minimum cultivation cost. It is important to identify and delineate suitable area for growing particular crop in order to harvest maximum yield. Therefore, an attempt has been made to delineate crop zones on the basis of soil characteristics and micro-climatic conditions.

2. Materials for Suitability Analysis

2.1. Land Resources Inventory Database

The land resources activity in Bangladesh was initiated in 1979 under the FAO/UNDP Land Use Advisory Project to make Soil Survey information as a basis for more rational planning of agricultural development. During the period 1980 to 1987 a national AEZ based computerized land resources database system was successfully developed with financial support from the UNDP and technical assistance from the FAO. This physical resources database on land, soils, climates, hydrology and land suitability was used for national and sub-national agricultural research and development planning. The Bangladesh Agricultural Research Council is the custodian of this database and is maintained at the Computer & GIS Unit. This was used in generating readily accessible and transferable information on biophysical resources, especially for researchers, extension personnel and decision makers in land and agricultural resources management and agricultural development planning. However, it was felt that considering only physical parameters in planning exercises is not adequate in addressing the intricacies of resource planning under the complex Bangladesh environmental conditions. Necessity was also felt that the database system needs to be updated and enlarged with new data on the socio-economic factors of agricultural production and with maps and appropriate production/resources management models.

A five-year project entitled "Utilization of AEZ Database and Installation of GIS for Agricultural Development", BGD/95/006-GIS at BARC, was launched with UNDP assistance in 1996 with the following objectives.

- Establish a GIS based computerized land information system at BARC.
- Utilize the AEZ/GIS database for technology generation and transfer on crop production, crop diversification and disaster preparedness programme planning with the incorporation of socio-economic data.
- Sensitize people involved in planning, decision-making process, research and education about the importance of AEZ/GIS as a planning tool.
- Develop manpower on GIS/decision support system, land resources and computer use.

Through this project all previous data has been transformed into a GIS. As GIS technology has the capability of simultaneous processing of spatial and related attribute data. The AEZ/GIS System Conceptual Design is presented in Figure 6. The technology being used to establish the LRIS includes ArcView GIS; the ArcView Spatial Analyst and Dialog Designer extensions; and Avenue, ArcView GIS software's programming language; as well as multicriteria analysis tools. Although one of the objectives of the

project was to incorporate socio-economic data in the database but not much was achieved in this aspect.

In the past, natural resources modeling systems were based on static GIS overlays. Due to the limited capacity of computers at the time, the overlay of individual maps, such as soil, climatic, and flood zone maps, was cumbersome, and much time was needed to refine the resulting layer. With the advent of more powerful desktop computer systems and more powerful software tools, such as ArcView GIS and ArcView Spatial Analyst, it has become possible to develop more flexible and dynamic modeling tools.

2.2. The Land Resources Inventory Application

The land resources inventory (LRI) application developed during 1997-2001 allows for the classification and mapping of soil characteristics from the LRI database. The LRI contains several attributes describing physical soil characteristics. Since LRI attribute data has a many-to-one relationship to soil mapping units, the data must first be summarized by the mapping unit and the resulting mix of LRI characteristics classified for mapping purposes. The LRI summary application was developed using the ArcView Dialog Designer extension. It allows the user to specify the study area, the data to be classified, and the number of classes to create. The user is then able to edit the resulting mix of classes based on the percentage area covered by each class. Classes can be merged and renamed to provide for more effective map output. An ArcView GIS-based application was developed to dynamically combine a user-specified DEM with the national (reconnaissance level) soil association layer to create a more detailed Soil Association by Inundation Land Type layer. The application was written in Avenue scripting language and uses the ArcView Spatial Analyst extension. The first step in development of this application was to refine a previously generated 300-meter DEM by filling in areas of missing elevation with values taken from a 1,000-meter DEM. Then, an Avenue programme was written to assign soil-association and topographically-derived "inundation land type" designations to each 300-meter grid cell. The output of this application is a new grid-based Soil/Inundation Land Type layer in which the number of many-to-one relationships between soil attributes and soil mapping units is greatly reduced. This new layer provides for a more explicit, accurate, and dynamic soil mapping capability (Broten et al, 2001). In Bangladesh, the following designations are used to specify a range of inundation depths based on the average peak water depth (Table 4).

The summarized LRI database contains 10471 records varying with 3596 soil associations and six land types combinations. Each record has 11 edaphic characteristics. Again, each edaphic characteristic has different classes. The edaphic characteristics with their classes are described in the

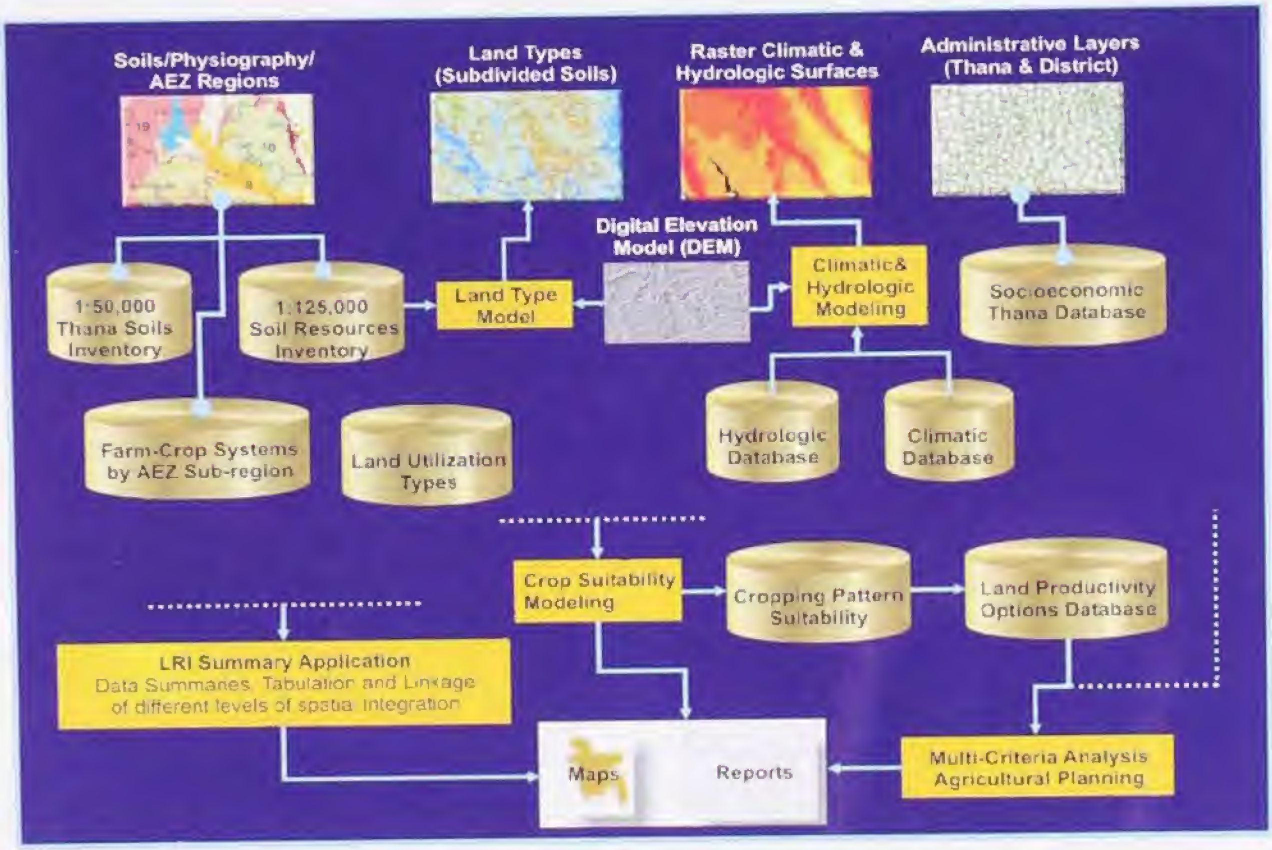

Figure 6. AEZ/GIS System Conceptual Design

following section (the basis of classification of 11 edaphic factors are presented in Table 10). Description of the edaphic parameters is heavily drawn from the Soil-Crop Suitability Classification for Bangladesh (Brammer, 1985) and the maps were generated using the LRI database.

Table 4. Distribution of land type by inundation

Land types	Characteristics	Areas (ha)
Highland (H)	Land above normal inundation	4,199,952
Medium Highland (MH)	Land normally inundated up to 90 cm deep. For some purposes, this is divided into MH-1: inundated up to 30 cm deep; MH-2: inundated 30-90 cm deep.	5,039,724
Medium lowland (ML)	Land normally inundated up to 90-180 cm deep	1,771,102
Lowland (L)	Land normally inundated up to 180-300 cm deep	1,101,560
Very lowland (VL)	Land normally inundated deeper than 300 cm	193,243

Source: Land Resources Appraisal of Bangladesh for Agricultural Development, (UNDP-FAO, 1988)

2.2.1. Soil Permeability

Three classes of permeability have been used, generalized from those of the USDA Soil Conservation Service. Lack of information prevents the use of the standard USDA classes.

Figure 7. Soil Permeability Map

Together with the drainage and inundation factors, permeability determines the oxygen availability in the root zone. Removal of excess moisture from the soil surface and the soil profile depends mainly on the rate of permeability and the position of the soil in the landscape. On high-lying land, rapidly permeable soils will generally not have water standing on the surface after heavy rainfall, and excess moisture in the root zone will be drained in a matter of a few hours. Slowly permeable soils, on the other hand, will have water standing on the surface for a period of time and may remain waterlogged for a few weeks after heavy rainfall. Actual durations of inundation and water logging are reflected in the inundation and drainage ratings. Under traditional management without irrigation, permeability will only be assessed in relation to non-seasonal rainfall and the ability to puddle the soil. However, when irrigation is part of land management, permeability is more important, particularly in the case of transplanted rice crops which can have a high irrigation requirement. The soil permeability map is shown in Figure-7.

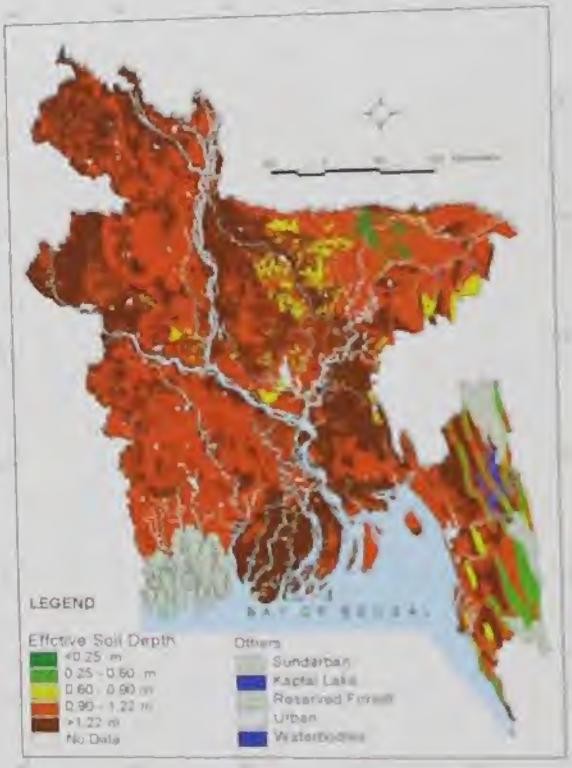

Figure 8. Effective Soil Depth Map

2.2.2. Effective Soil Depth

The soil depth ratings do not simply indicate the depth to bedrock or cemented material. It has been assumed that, with increasing compactness and consistence, the effective rooting depth will decrease, particularly in the case of annual dryland crops. Effective soil depth map is shown in Figure-8.

For example, root development will not be hampered in a 127 cm (fifty inches) deep profile of friable sandy loam. On the other hand, roots will not easily penetrate into a very firm clay and, consequently, depending on the crop, the effective soil depth would be less than 127 cm. Soils that have bedrock or cemented material within the upper 127 cm will either receive a 'd3' or 'd4' rating. Soils with a well-developed, ploughpan receive a 'd5' rating (See Table 10).

2.2.3. Available Moisture Holding Capacity

The available moisture holding capacity is determined for the calculated effective soil depth. Volume percentage of available moisture has been determined in the laboratory for a large number of soil samples, representing all textural classes and parent materials. On the basis of these figures, five classes have been established, ranging from more than 400 mm (16 inches) to less than 100 mm (4 inches) of available moisture. At first glance, the available moisture figures and the selected class limits might appear rather high. However, research over a number of years has repeatedly shown that Bangladesh's fioodplain soils in particular have very high available moisture holding capacities.

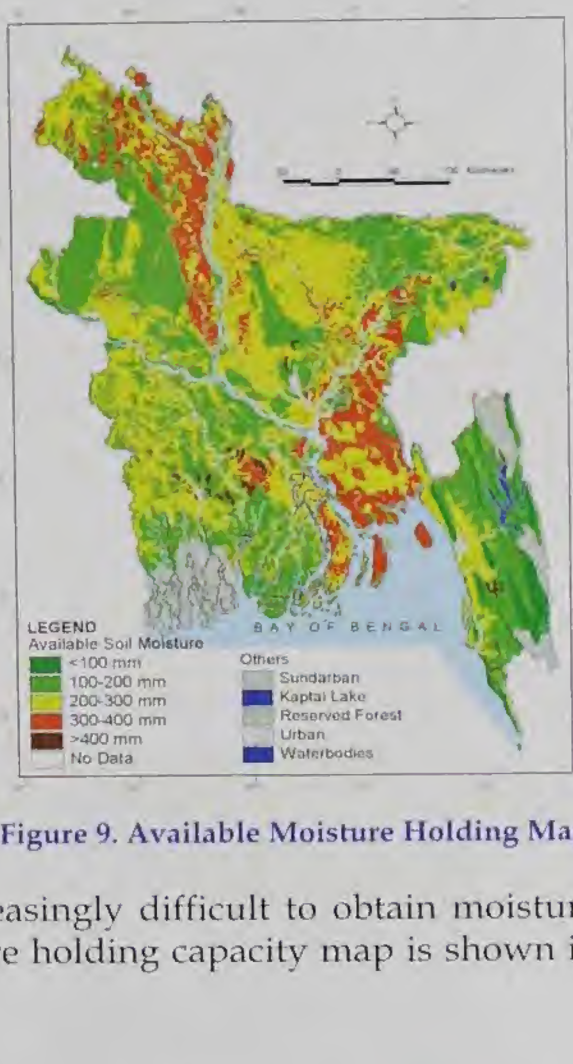

Figure 9. Available Moisture Holding Map

With regard to the class limits, it must be realized that these represent 'total available moisture' rather than 'readily available moisture'. The latter is generally only 50 to 60 percent of the total available moisture; plants find it increasingly difficult to obtain moisture beyond these levels. Available moisture holding capacity map is shown in Figure-9.

2.2.4. Nutrient Availability

A simple nutrient classification was developed by making a separation between soils that have low cation exchange capacities (CEC), low base saturation and/or low amounts of weatherable minerals, and soils that do not have these properties. Soils developed in coarse textured parent material - sand, loamy sand and sandy loam - have a small clay fraction, a CEC generally well below 10 me/100 g soil and, in addition; the amount of weatherable minerals is relatively low. Soils developed in strongly

weathered Madhupur Clay have a very low mineral reserve, are known to fix phosphates and have a clay fraction dominated by kaolinite. Ferrolysed soils have an inert clay fraction with a low CEC. All other soils in Bangladesh have very high to moderate cation exchange capacities and high mineral reserves. Nutrient availability map is shown in Figure-10.

Figure 10. Nutrient Availability Map

2.2.5. Soil Reaction

In rating the soils for acidity/alkalinity, emphasis has been given to the reaction of the A horizon. This is achieved by giving this horizon more weight than the reaction in the deeper parts of the soil. Ratings are based on the pH determined in the field and a correction must be applied, when only the laboratory pH is known.

Accumulation of exchangeable sodium is restricted to very small patches of Ganges river floodplain soils and is insignificant in terms of acreage. Such soils have a very high pH (pH 7.3-8.4) in the surface soil and will receive an 'a4' rating, with limitations assigned accordingly. Too little is known about them to introduce a separate 'soil sodicity' land factor. Soil reaction map is shown in Figure-11.

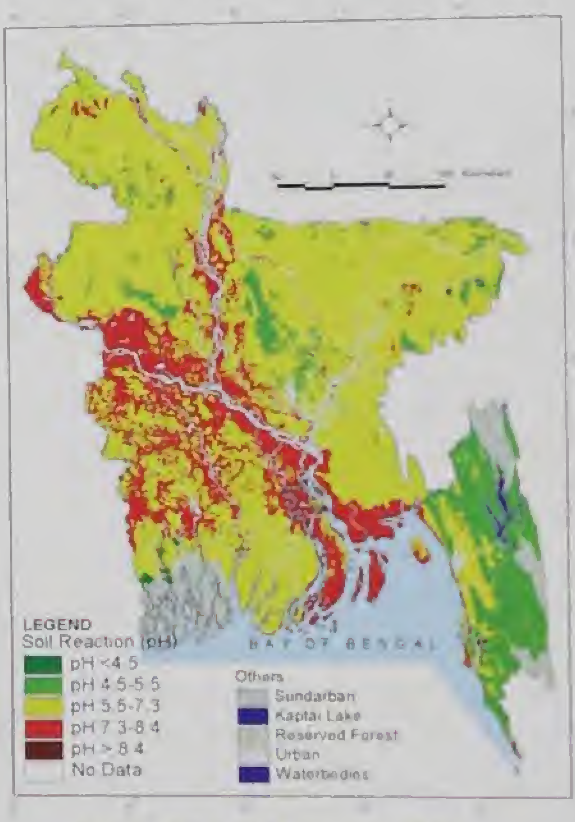

Figure 11. Soil Reaction Map

2.2.6. Soil Salinity

Saline soils are mainly found on land which is subject to tidal flooding with salt water for part or all of the year and on land where the groundwater is to some extent saline: i.e., on the Ganges tidal floodplain, the Young Meghna estuarine floodplain and near river mouths on the Chittagong coastal plain. More than 30% of the cultivable land in Bangladesh is in the coastal area. Out of 2.86 Mha of coastal and offshore lands about 1.056 Mha of lands are affected by different

degrees of salinity.

The salinity has limited effect on cropping during khrif-l season because most salts are washed on by heavy monsoon rainfall or flooding with fresh river water. Therefore, soils that are saline in the dry season generally become non-saline in the root zone during the monsoon season.

During the dry season, capillary movement of moisture to the soil surface concentrates salts in a thin layer at the surface. Where the salt concentration occurs early in the dry season, rabi crops cannot be grown. On such land, as well as on soils where salinity develops later in the dry season, kharif crops cannot be sown or transplanted until there has been sufficient pre-monsoon or monsoon rainfall to dilute or leach the salts from the topsoil. Soil salinity map is shown in Figure-12.

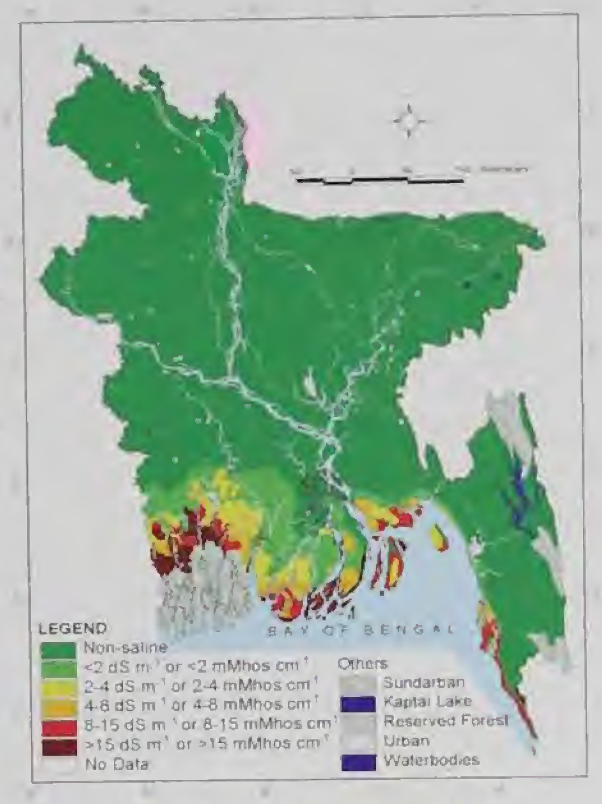

Figure 12. Soil Salinity Map

2.2.7. Topsoil Consistence and Bearing Capacity

This land factor serves to evaluate the workability of the soils. Organic soils have a low bearing capacity which adversely affects the trafficability of the land during land preparation and planting. Heavy consistencies in mineral topsoils indicate the likelihood of tillage difficulties. Such soils are also difficult to work into a fine tilth which will particularly affect the germination and early development stage of crops which are broadcast sown. Top soil consistency map is shown in Figure-13.

Figure 13. Topsoil Consistency Map

2.2.8. Drainage

The drainage classes are the same as those used to describe soils in the field. Poorly drained soils have been

subdivided into early/normal and late draining soil phases respectively. The definitions of the drainage classes are as follows:

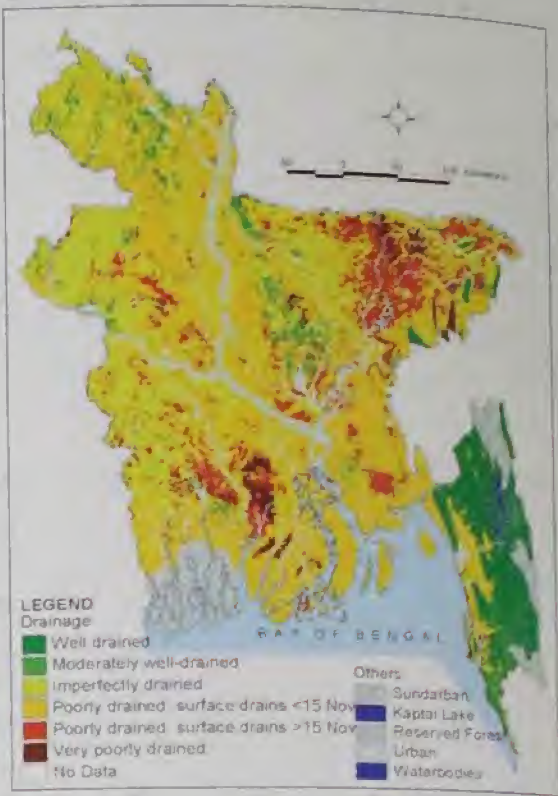

Figure 14. Drainage Map

Water stands on the surface for not more than a few hours and the soil does not remain saturated for more than 2-3 days after heavy rainfall is categorized as well drained soil.

Moderately well drained soils are those where water remains on the soil surface for a few days following heavy rainfall and the soil may remain wet for up to two weeks at a time during the monsoon season.

Where the soil remains wet for several weeks during the monsoon season and water may stand on the surface for up to two weeks at a time following periods of heavy monsoon rainfall is categorized as imperfectly drained soil.

Poorly drained soils are those which remain wet for several weeks during the monsoon season and are flooded for more than two weeks but not for the whole year and soils those which remain wet throughout the year are termed as very poorly drained soils. Drainage map is shown in Figure-14.

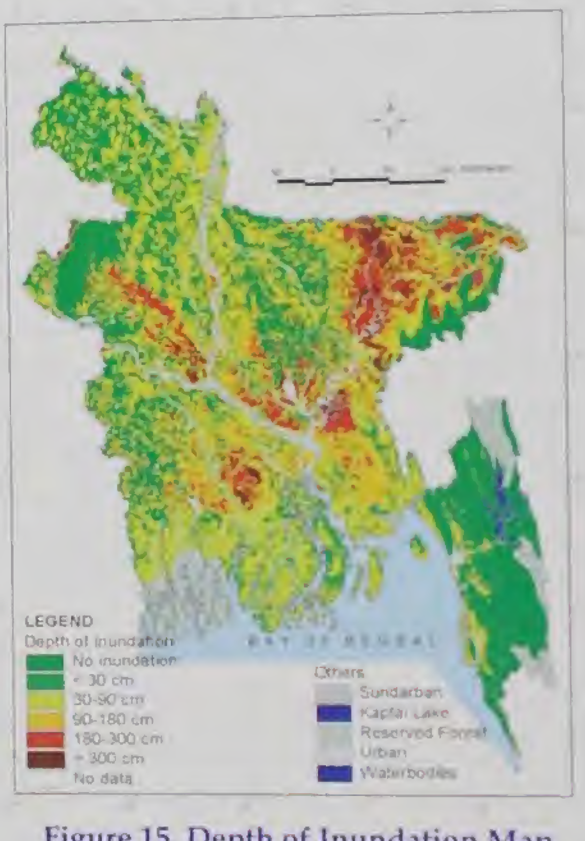

Figure 15. Depth of Inundation Map

2.2.9. Depth of Inundation

Inundation may be caused by groundwater levels rising above the land surface, by ponding of rain water, or overflow from a river. Water levels rise and fall slowly, there is not more than negligible flow of the water, and water stands on the surface for more than 2-3 days at a time. Poorly and very poorly drained soils, by definition, are inundated during part or all of the year respectively; imperfectly drained soils can be inundated

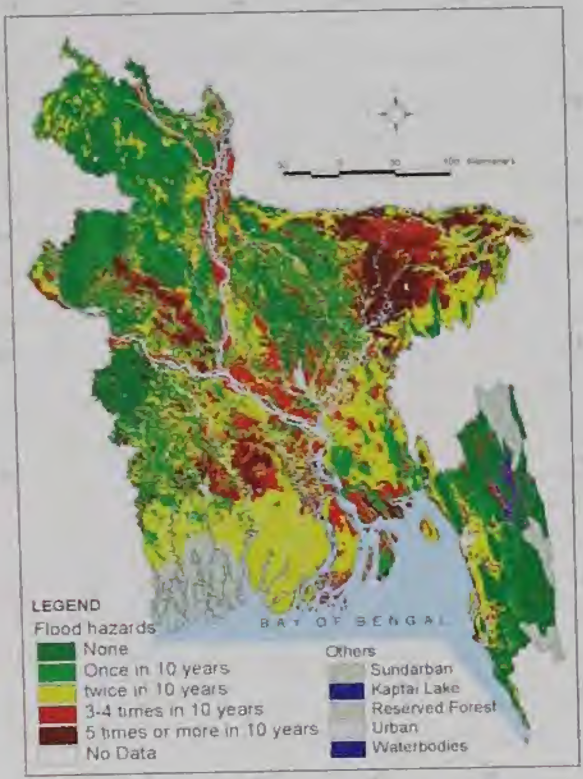

Figure 16. Flood Hazard Map

occasionally and moderately well and well drained soils are never inundated. The depth of inundation is particularly important in relation to the type of kharif rice crop to be grown. Depth of inundation map is shown in Figure-15.

2.2.10. Flood Hazard

The flood hazard is evaluated through the number of 'disastrous' floods which, occur during a period of time. Disastrous flooding can be caused by river spilling over their banks, eroding land or depositing fresh alluvium on neighbouring land; by flash floods flowing- from adjoining hill areas; by rain-water accumulating in deep floodplain basins; or by tidal storm surges associated with cyclones. In particular, late dry season crops such as boro and the early kharif crops such as aus and jute can be damaged by flooding; and later river floods and flash floods from adjoining hill areas can damage transplanted aman. On the other hand, early and mid-dryland rabi crops are not normally affected. Flood hazard map is shown in Figure-16.

2.2.11. Slope

The land factor 'slope' is used to evaluate both erosion hazard and ease of land management. Although it is realized that there are better methods for evaluating erosion hazard, lack of relevant information does not allow this at present. On the other hand, climate - rainfall distribution and intensity - and soil are relatively uniform in the hill areas and the slope percentage is at least one of the dominant factors which determine the erosion hazard. Slope map is shown in Figure-17.

Figure 17. Slope Map

2.3. Climate

A tropical monsoon climate with hot, wet summers and cool, dry winters prevails throughout Bangladesh. Only those crops that can be grown under these climatic conditions have been evaluated. For rainfed agriculture - still by far the most common form of agriculture in Bangladesh - the distribution of rainfall over an annual period is very important, particularly since it determines whether one or two good kharif rice crops can be grown. Only in the north-east of the country is the rainy season sufficiently long to allow two transplanted rice crops of normal duration to be grown reliably in rotation without irrigation, but the excessive rainfall, cloudiness and humidity in this area provide a limitation. In the centre of the country, aus and T. aman can be grown in rotation only when quick-maturing varieties are grown. In the west, the rainy season is too short and uncertain for more than one kharif rice crop to be grown reliably without irrigation. Where irrigation is available, the length of the growing season is irrelevant, but excessive rainfall remains a constraint for paddy crops in the east and for kharif dryland crops in all areas.

2.3.1. Pre-Kharif Transition Period

The pre-kharif transition period in Bangladesh is characterized by unreliable rainfall, varying in timing, frequency and intensity from year to year, and providing only an intermittent supply of moisture for crops growing during this period. This period is considered to start on the first date after end of February when precipitation first exceeds 0.5 PET (potential evapo-transpiration). The period ends on the date from which precipitation continu-ously exceeds 0.5 PET (i.e., the beginning date of the kharif growing period). During this transition period, soils are intermittently moist and dry, the relative lengths and frequency of such periods depending on the timing and intensity of pre-monsoon rainfall occurring during this season in individual years.

Six zones pre-kharif transition period have been recognized (Table 5). They range from zone P1, with a mean length of 10-20 days, in Sylhet

Table 5. Mean duration, starting date and end date of reference pre-kharif growing period (P)

Zone	Duration (days)		Start date (S)		End date (B)	
	Mean	SD (range)	Mean	SD (days) (range)	Mean	SD (days) (range)
P1	10-20	15-20	17 March	5-15	2 April	10-20
P2	20-30	15-20	20 March	5-15	14 April	10-20
P3	30-40	15-30	22 March	5-25	26 April	10-30
P4	40-50	20-30	24 March	5-25	8 May	10-30
P5	50-60	20-30	24 March	5-25	18 May	10-30
P6	60-70	20-30	17 March	5-25	21 May	10-30

S = Start of pre-kharif transition period, B = Beginning of reference kharif growing period
SD = Standard deviation

Figure 18. Pre-Kharif Transition Period

District and the north-east of Sunamganj District, to zone P6, with a mean length of more than 60 days, in the west of Jessore and Satkhira Districts.

The mean number of dry days within these periods i.e., the aggregate length of the periods when the balance between precipitation and potential evapotranspiration falls below 0.5 PET - increases from 1-9 days in zone P1 to 39-48 days in zone P6. Except in zone P1, the mean number of dry days is more than half the total length of the period, indicating a considerable drought hazard to rainfed crops growing during this period, especially in the west of the country. On the other hand, the short duration of the transition period in zone P1, together with the associated rapid transition to humid (i.e., excess rainfall) conditions, also provides a hazard for direct seeded crops such as broadcast aus and jute which may not be able to attain sufficient height after germination to withstand excess rainfall on impervious soils (Figure-18).

2.3.2. Kharif Growing Period

The main length of growing period zones shown on the agroecological map represent the kharif growing period (K100). Using isolines at 10-day intervals, twelve zones have been shown, ranging from 170-180 days in the extreme west (K1) to 280-290 days in the extreme north-east (K12). The kharif growing period is the period when the moisture supply from rainfall plus soil storage is sufficient to support non-irrgated kharif crops. The period begins on the date from which precipitation continuously exceeds 0.5 PET and ends on the date when the combination of precipitation plus an

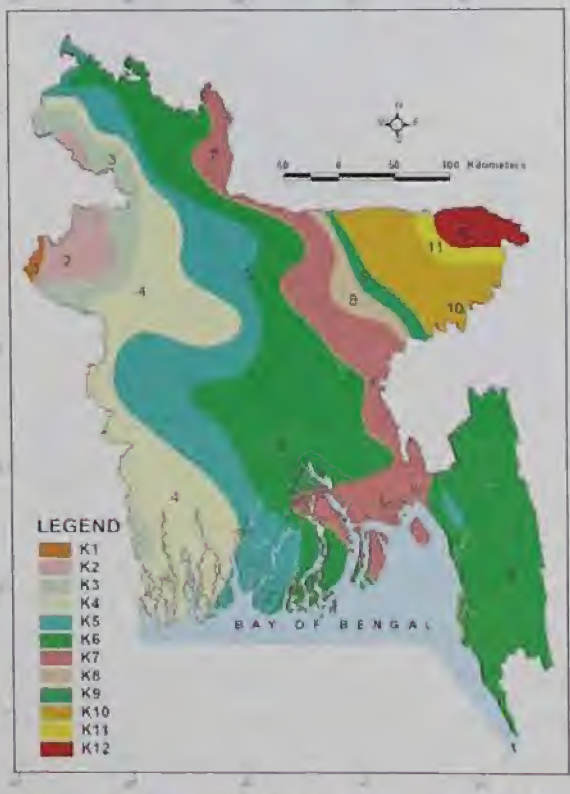

Figure 19. Kharif/Rabi Growing Period Map

assumed 100 mm of soil moisture storage after the rainy season falls below 0.5 PET. For the greater part of this period, precipitation exceeds full PET and water can be held on the surface of impermeable soils by bunds; this period of excess precipitation is termed the humid period (Table 6). Kharif/Rabi growing period map is shown in Figure-19.

Table 6. Mean duration, begin date and end date of reference kharif growing period (K100)

Zone	Duration (days)		Begin date (B)		End date (E100)	
	Mean	SD (range)	Mean	SD (days) (range)	Mean	SD (days) (range)
K1	170-180	20-30	27 May	20-30	18 Nov	20-25
K2	180-190	20-30	24 May	20-30	24 Nov	20-25
K3	190-200	20-40	21 May	10-30	2 Dec	20-35
K4	200-210	20-40	16 May	10-30	9 Dec	20-35
K5	210-220	20-40	9 May	20-30	10 Dec	20-35
K6	220-230	20-40	3 May	10-30	14 Dec	20-35
K7	230-240	20-40	27 April	10-30	18 Dec	20-35
K8	240-250	20-40	24 April	10-20	25 Dec	20-35
K9	250-260	20-40	18 April	10-20	29 Dec	20-35
K10	260-270	20-30	12 April	10-20	2 Jan	20-35
K11	270-280	20-30	3 April	10-20	3 Jan	25-30
K12	280-290	20-30	27 March	10-20	6 Jan	55-30

B = Beginning of reference kharif growing period, E100 = End of reference kharif growing period, SD = Standard deviation

2.3.3. Rabi Growing Period

The agroclimatic map legend shows the length of rabi growing period in each of the twelve kharif length of growing period zones shown on the agroecological map. The rabi growing period is defined as the period between the end of the humid period (when rainfall exceeds PET) and the time when 250 mm of soil moisture have been exhausted by evapotranspiration (i.e., between points EH0 and E250). The mean length of the rabi growing period ranges from 100-120 days in the extreme west to 140-150 days in the north-east. For the rabi growing period, it is assumed that dryland crops can use moisture stored down to 1.25 m (Table 7).

2.3.4. Thermal Zones

Two kinds of thermal zones are shown on the agroecological map. The major zones show differences in the length of the cool winter period. Subzones show differences in the number of days with extremely high summer temperature. Temperatures during the monsoon season are relatively uniform all over the country, and separate zones have not been defined for this period (Table 8). Thermal zone map is shown in Figure-20.

Table 7. Mean duration, begin date and end date of rabi growing period (R250)

Zone	Duration (days)		Begin date (EH0)		End date (E250)	
	Mean	SD (range)	Mean	SD (days) (range)	Mean	SD (days) (range)
K1	105-115	10-20	12 Oct	20-25	30 Jan	30-35
K2	115-125	10-20	15 Oct	20-25	12 Feb	30-35
K3	115-135	10-30	15 Oct	20-30	17 Feb	20-30
K4	115-135	10-30	15 Oct	20-30	17 Feb	20-35
K5	120-140	10-30	15 Oct	20-30	22 Feb	20-35
K6	120-145	10-30	21 Oct	15-30	2 Mar	20-35
K7	120-145	10-30	24 Oct	15-30	5 Mar	20-30
K8	135-150	10-30	24 Oct	15-25	15 Mar	15-30
K9	135-150	10-30	27 Oct	15-25	18 Mar	15-30
K10	135-150	10-30	27 Oct	15-25	18 Mar	15-30
K11	135-150	20-30	1 Nov	15-20	22 Mar	15-25
K12	135-150	20-30	3 Nov	15-20	25 Mar	15-20

EH0 = End of kharif humid moisture period, E250 = End of reference rabi growing period
SD = Standard deviation

Table 8. Thermal zone

Numeric Code	Symbol	Description: No. of days in Rabi (winter) with min temp < 15° C
1	T1	30-40
2	T2	40-50
3	T3	50-70
4	T4	70-90
5	T5	90-100

Figure 20. Thermal Zones Map

2.3.5. Rabi Temperature Zones

Five zones are shown on the agroecological map indicating differences in the length of the cool winter period. In general, the longer that mean daily temperatures are below 20°C or minimum temperatures are below 15° C, the greater is the climatic suitability for temperate crops such as wheat, potato, mustard and lentil. Conversely, minimum temperatures below 20° C may interfere with pollination in aman paddy, and minimum temperature below 15° C retard vegetative growth in HYV boro paddy; (however, the performance of local boro paddy varieties is less affected by cold than that of existing HYVs).

The mean length of the cool winter period increases from 30-40 days on the coast to about three months in the north-west and north-east. The deep inland penetration of the T3 zone (50-75 days with minima below 15° C) in the east of the country is explained by the dampening effect on temperatures of the large expanses of water remaining in the Sylhet Basin during the winter months.

This zonal distribution of winter temperatures has important implications for the cultivation of rabi crops and boro paddy. It indicates that climatic conditions for wheat, potato and rabi pulses are most suitable in the north-western half of the country. On the other hand, conditions are least suitable in the north-west for early planting of HYV boro. That is especially so on upland sites irrigated by tube-wells; however, minimum temperatures may be moderated in bil areas, as in the Sylhet Basin, but individual bils cannot be shown separately on the map scale used.

Figure 21. Extreme Temperature Zones Map

2.3.6. Extreme Summer Temperature Zones

The average number of days per year when maximum temperatures exceed 40°C is delineated on the agroecological map as subzones of the rabi temperature zones. Four such subzones are shown: less than 0.5 days; 0.5-5 days; 5-9 days; and 10-15 days: see Table 9. The zones with five days or more with such extremely high temperatures lie in the west of the country. In the centre, east and south of the country, such temperatures are rarely experienced; at Dhaka, the average is 1 day in 2 years.

These extremely high temperatures usually occur in April-May, occasionally in early June. Their significance is that they create a very high potential evapo- transpiration demand which plant roots may not be able to satisfy, especially in kharif crops at the seedling stage. The occurrence of such high temperatures - almost always accompanied by very low humidity and often by a strong mid-day wind - can prevent pollination of HYV boro paddy if they occur when crops are at the panicle initiation or flowering stages. Extreme temperature zones map is shown in Figure-21. The combined agro-climatic zones map is shown in Figure-22.

Table 9. Extreme summer temperature zones

Numeric Code	Symbol	Description No. of days in Kharif (summer) with maximum temperature greater than 40° C
1	El	<0.5
2	E2	0.5-5
3	E3	5-10
4	E4	>10

Figure 22. Combined Agro-climatic Map

2.4. Crop Suitability Assessment

Bangladesh soil and climatic conditions is suitable for growing wide range of both tropical and temperate crops. The major crops cultivated in the country are rice, wheat, maize, sugarcane, potato, jute, pulses, oilseeds, spices and vegetables. Cereals and potato production fulfils the country's requirement. Other crop productions are deficient in the country. To meet the demand a huge amount of foreign currency is spent for importing sugar, pulses, oilseeds and spices every year. The deficiency of some crops can be minimized through increase of production in a suitable land with a minimum cultivation cost. It is important to identify and delineate suitable area for growing particular crop in order to harvest maximum potential yield. Therefore, an attempt has been made to assess the land-crop suitability.

2.4.1. Procedure

The soil, inundation and landform data of land resources inventories of BARC were used for crop suitability assessment and classification. The climate data maintained at BARC was utilized for climatic analysis. The administrative boundaries maps, land type and soil association grids of 300 meter pixel size and point shape file of climate stations of Bangladesh Meteorological Department (BMD) were used for the study. The mapping scale is 1:250,000. The mapped information was prepared by using ArcView 3.2 and Spatial Analyst GIS software.

The agro-edaphic and agro-climate suitability has been determined separately based on the soil/land factors and climatic factors. Expert knowledge of scientists and extension personnel and available information (Appendix Tables 1-12) has been used in characterizing the agro-edaphic and agro-climate suitability. Afterwards, land suitability for different crops has been done through overlaying of agro-edaphic and agro-climatic suitability layers. The cartographic models of the processes involved in generating crop suitability maps are presented in Figure-23.

2.4.2. Edaphic Suitability Analysis

In order to assess the suitability of a soil/land for any of the land use types (LUT) or individual crops, the total number and degree of limitations, as provided by the land factor classes, must, be determined. Five degrees of limitation have been recognized:

- 0 - no limitation, representing the most favourable condition;
- 1 - slight limitation;
- 2 - moderate limitation;
- 3 - severe limitation;
- 4 - very severe limitation; the soil is unsuitable for the land use type or particular crop under consideration at the specified level of management.

To perform the task of agro-edaphic suitability, firstly, the degrees of limitation (with respect to crop requirements) of each individual land factors (Table-10) for the production of crops were assessed. Accordingly degrees of limitation were imposed to each land/soil factor classes. This was done on a scale of 0-4 and the basis of expert judgment from the NARS scientists and other experts who have wide knowledge and field experience on cultivation of crops.

Secondly, a customized programme developed in Microsoft Excel software was used to prepare a land utilization table (LUT) on the basis of combined limitation ratings composed of individual land factor constraints for a particular crop. The soil association by land type file (Ltsoil) of LRI, which has 10471 records and contains attributes of 11 land factors (as shown in Table 10), was used for this study. Limitations were assigned to land

factors for each land phase via a lookup table. Limitations imposed for different land factors for crops are shown in Table-11. Then the degree of limitations assigned to land factors under each land phase was counted. An example of how the values in each category (Assigned limitations) are concatenated to get combined limitation ratings is shown in Table 11. Afterwards, an overall suitability rating for each land phase is derived based on the combined limitation ratings using the set of rules as shown in Table 12. This is accomplished on the basis of Zijsvelt's soil-crop suitability model which was introduced in 1979 revised by Brammer in 1985 and further revised by Hussain et al, 2005.

The next step was to create a database file (dbf) with LTSOIL, respective crops fields for joining to the Ltsoil (grid) file using the LTSOIL fields which is common in both the files. Finally, ArcView 3.2 GIS software was used to generate agro-edaphic suitability maps of different crops and delineate areas by different suitability class. To get the edaphic suitability of crops, the database file as prepared joined to the Ltsoil (grid) shape file in ArcView using the common fields to generate crop suitability maps. The extent under each suitability class can be summarized by districts/upazilas through overlaying of districts/upazilas boundary and edaphic suitability layer.

Relationship between suitability rating, and number and degree of limitations is shown in Table-13.

2.4.3. Climate Suitability Analysis

To carry out the task of agroclimate suitability, similar approach were followed considering length of kharif growing period, pre-kharif transition period, thermal zone and extreme temperature.

2.4.4. Combined Suitability Analysis

In the final stage of land suitability assessment, the agro-edaphic and agro-climatic suitability maps were overlaid to get the overall land suitability maps of different crops. The overlaying of suitability maps was done using Map calculator of ArcView GIS software. The Rules for combining these maps to get classification of land suitability maps is presented in Table 14.

The cartographic model presented in Figure 23 summarizes the processes involved in determining the agro-edaphic, agro-climatic and overall suitability of the selected crops and finally, the crop zoning.

The suitability maps of different crops have been prepared following the above procedures. The maps show the potential areas under different suitability class i.e. very suitable, suitable, moderately suitable, marginally suitable and not suitable. The crops are rice (Boro, T. Aus, T. Aman), wheat, kharif maize, potato, mustard, groundnut, lentil, mungbean/blackgram, gram (chickpea), onion/garlic, rabi chilli, sugarcane and jute.

Table 10. Land factor classes, code descriptions and ratings

Codes	Land factor Descriptions		Rating
p1	Soil Permeability	Slow (< 12 cm d^{-1})	1
p2		Moderate (12-305 cm d^{-1})	2
p3		Rapid (< 305 cm d^{-1})	3
d1	Effective Soil Depth	< 0.25 m	1
d2		0.25 - 0.60 m	2
d3		0.60 - 0.90 m	3
d4		0.90 - 1.22 m	4
d5		> 1.22 m	5
d6		Very firm/hard ploughpan	6
m1	Available Soil Moisture	< 100 mm	1
m2		100-200 mm	2
m3		200-300 mm	3
m4		300-400 mm	4
m5		> 400 mm	5
n1	Nutrient Status	Low	1
n2		High	2
a1	Soil Reaction (pH)	pH < 4.5	1
a2		pH 4.5-5.5	2
a3		pH 5.5-7.3	3
a4		pH 7.3-8.4	4
a5		pH > 8.4	5
s1	Soil Salinity	< 2 dS m^{-1} or < 2 mMhos cm^{-1}	1
s2		2-4 dS m^{-1} or 2-4 mMhos cm^{-1}	2
s3		4-8 dS m^{-1} or 4 -8 mMhos cm^{-1}	3
s4		8-15 dS m^{-1} or 8 -15 mMhos cm^{-1}	4
s5		> 15 dS m^{-1} or > 15 mMhos cm^{-1}	5
t1	Soil Consistency	not more than slightly firm, slightly sticky, slightly plastic, hard	1
t2		firm, very firm, sticky, plastic, hard, very hard	2
t3		extremely firm, very sticky, very plastic, extremely hard	3
t4		organic material to at least 25 cm below the surface	4

Codes	Land factor Descriptions		Rating
w1	Drainage	Well drained	1
w2		Moderately well-drained	2
w3		Imperfectly drained	3
w4		Poorly drained, surface drains < 15 Nov	4
w5		Poorly drained, surface drains > 15 Nov	5
w6		Very poorly drained	6
i1	Depth of inundation	No inundation	1
i2		< 30 cm	2
i3		30-90 cm	3
i4		90-180 cm	4
i5		180-300 cm	5
i6		> 300 cm	6
f1	Flood hazards	None	1
f2		Once in 10 years	2
f3		twice in 10 years	3
f4		3-4 times in 10 years	4
f5		5 times or more in 10 years	5
e1	Slope	< 3 percent	1
e2		3-8 percent	2
e3		8-16 percent	3
e4		16-30 percent	4
e5		30-45 percent	5
e6		> 45 percent	6

Table 11. Degree of limitations imposed … factors for different crops

Code	Degree of Limitations														
	Aus	Aman	Boro	Wheat	Maize	Potato	Lentil	Mungbean/ Blackgram	Gram	Mustard	Gnut	Chili	Onion/ Garlic	Sugar-cane	Jute
p1	0	0	0	2	2	2	1	1	1	2	3	1	2	2	0
p2	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0
p3	2	2	4	2	2	1	2	2	3	2	0	1	0	1	1
d1	3	2	2	2	3	2	3	2	4	1	2	2	2	2	0
d2	1	0	1	0	2	0	1	1	3	0	0	1	0	1	0
d3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
d4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
d5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
d6	0	0	0	2	2	3	3	3	1	2	4	2	4	2	0
m1	4	2	3	2	2	3	3	2	2	2	2	3	3	2	3
m2	1	0	0	1	1	0	0	0	1	0	1	1	0	0	1
m3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
m4	0	0	0	2	1	3	4	3	3	1	1	3	3	3	0
m5	0	0	0	4	3	4	4	4	4	4	4	4	4	4	1
n1	1	1	1	2	2	2	1	2	1	2	2	2	2	2	1
n2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a1	3	2	2	1	2	1	4	3	4	2	2	2	4	1	2
a2	1	1	0	1	1	0	4	2	4	1	1	0	3	0	1
a3	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
a4	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0
a5	2	1	2	2	2	1	2	2	2	2	2	3	3	1	3
s1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
s2	1	1	2	0	2	1	3	1	3	1	1	0	1	1	2
s3	2	2	3	1	4	2	4	2	4	3	2	1	4	2	3
s4	3	2	4	2	4	4	4	4	4	4	3	2	4	3	3
s5	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4
t1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
t2	0	0	0	2	1	2	1	1	0	1	2	1	2	0	0
t3	0	0	0	3	3	3	4	3	2	3	4	2	4	1	1
t4	3	3	1	4	4	4	4	4	4	4	4	3	4	3	2
w1	4	3	4	0	0	0	1	1	1	0	0	0	0	0	0
w2	2	2	3	0	0	0	1	1	0	0	0	0	0	0	0
w3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
w4	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0
w5	0	0	0	3	3	4	4	2	4	3	3	4	4	4	2
w6	1	0	0	4	4	4	4	4	4	4	4	4	4	4	4
i1	2	0	2	1	0	1	0	1	0	2	2	2	2	0	2
i2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
i3	0	0	0	0	1	0	1	0	0	0	0	0	0	2	0
i4	2	2	0	2	3	1	3	3	2	1	1	1	1	4	0
i5	3	4	0	4	4	3	4	4	3	4	4	4	3	4	0
i6	4	4	0	4	4	4	4	4	4	4	4	4	4	4	4
f1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
f3	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0
f4	2	3	1	0	2	0	0	0	0	0	0	0	0	3	2
f5	3	4	2	0	3	0	0	0	0	0	0	0	0	3	4
e1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
e2	2	2	2	2	1	3	1	1	1	1	1	1	1	0	1
e3	4	4	4	4	3	4	2	2	3	4	3	3	3	2	4
e4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
e5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
e6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

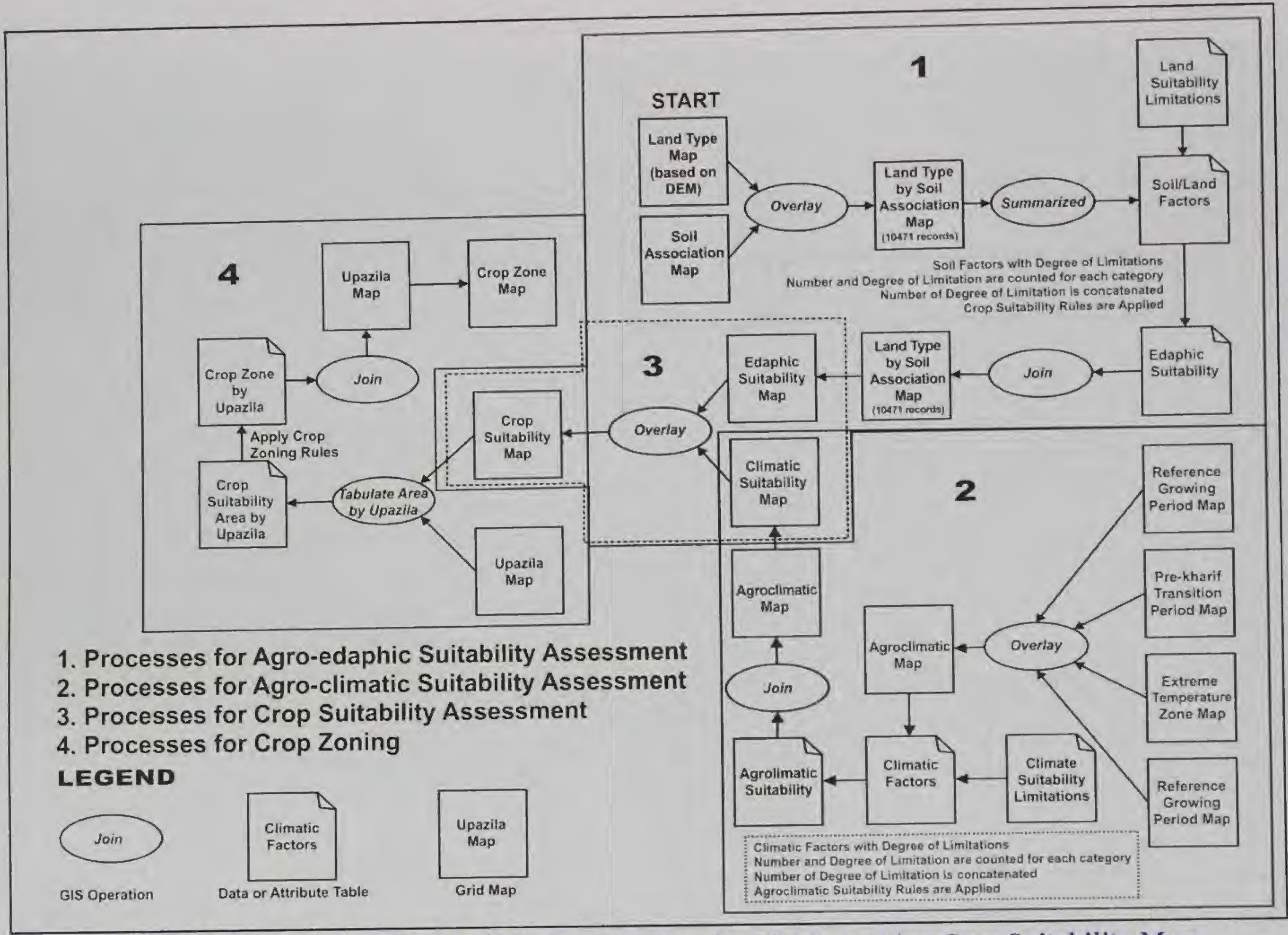

Figure 23. Cartographic Model of the Processes involved in Generating Crop Suitability Maps

Table 12. Assigned limitations and number, degree of limitations and suitability

Assigned Limitations											Degree of limitations and Count					COMB_SEV	Suitability
E	D	M	P	W	T	A	N	S	I	F	NONE	MOD	SEV	VSEV	ESEV		Lentil_SUIT
0	2	0	1	3	0	0	1	0	0	1	6	3	1	1	0	6-3-1-1-0	4
0	2	0	1	4	0	0	1	0	4	1	5	3	1	0	2	5-3-1-0-2	5
0	0	0	0	4	0	0	1	0	4	2	7	1	1	0	2	7-1-1-0-2	5
0	0	0	0	4	0	0	1	0	4	3	7	1	0	1	2	7-1-0-1-2	5
0	0	0	0	4	0	0	1	0	4	4	7	1	0	0	3	7-1-0-0-3	5
0	2	0	1	1	0	1	1	0	0	0	6	4	1	0	0	6-4-1-0-0	3
.....	.....																
0	0	0	3	4	0	2	1	3	4	2	4	1	2	2	2	4-1-2-2-2	5

None = No limitation, Mod = Moderate limitation, SEV= Severe Limitation, VSEV= Very severe limitation, ESEV= Extremely severe limitation

Table 13. Relationship between suitability rating and number and degree of limitations

Code	Description	Percent MAT (Maximum Attainable Yield)	Number and degree of limitations	Concatcode 0-1-2-3-4	Edaphic Suitability
S1	Very Suitable	80 percent or more of MAT	All 0	11-0-0-0-0	1
			One 1, and rest 0	10-1-0-0-0	1
			Two 1, rest 0	9-2-0-0-0	1
S2	Suitable	60 to 80 percent of MAT	Three 1, rest 0	8-3-0-0-0	2
			Four 1, rest 0	7-4-0-0-0	2
			One 2, rest 0	10-0-1-0-0	2
			One 2, one 1, rest 0	9-1-1-0-0	2
			One 2, two 1, rest 0	8-2-1-0-0	2
			Two 2, rest 0	9-0-2-0-0	2
S3	Moderately Suitable	40 to 60 percent of MAT	Five 1, rest 0	6-5-0-0-0	3
			Six 1, rest 0	5-6-0-0-0	3
			One 2, three 1, rest 0	7-3-1-0-0	3
			One 2, four 1, rest 0	6-4-1-0-0	3
			Two 2, one 1, rest 0	8-1-2-0-0	3
			Two 2, one 2, rest 0	7-2-2-0-0	3
			Three 2, rest 0	8-0-3-0-0	3
			One 3, rest 0	10-0-0-1-0	3
			One 3, one 1, rest 0	9-1-0-1-0	3
			One 3, two 1, rest 0	8-2-0-1-0	3
			One 3, one 2, rest 0	9-0-1-1-0	3
			One 3, one 2, one 1, rest 0	8-1-1-1-0	3
			Seven 1, rest 0	4-7-0-0-0	4
			Eight 1, rest 0	3-8-0-0-0	4
			Nine 1, rest 0	2-9-0-0-0	4

Code	Description	Percent MAT (Maximum Attainable Yield)	Number and degree of limitations	Concatcode 0-1-2-3-4	Edaphic Suitability
S4	Marginally Suitable	20 to 40 percent of MAT	One 2, five 1, rest 0	5-5-1-0-0	4
			One 2, six 1, rest 0	4-6-1-0-0	4
			Two 2, three 1, rest 0	6-3-2-0-0	4
			Two 2, four 1, rest 0	5-4-2-0-0	4
			Three 2, one 1, rest 0	7-1-3-0-0	4
			Three 2, two 1, rest 0	6-2-3-0-0	4
			Four 2, rest 0	7-0-4-0-0	4
			One 3, three 1, rest 0	7-3-0-1-0	4
			One 3, four 1, rest 0	6-4-0-1-0	4
			One 3, one 2, two 1, rest 0	7-2-1-1-0	4
			One 3, one 1, three 1, rest 0	6-3-1-1-0	4
			One 3, one 1, four 1, rest 0	5-4-1-1-0	4
			One 3, two 2, rest 0	7-1-2-1-0	4
			One 3, two 2, one 1, rest 0	8-0-2-1-0	4
			Two 3, rest 0	9-0-0-2-0	4
			Two 3, one 1, rest 0	8-1-0-2-0	4
N	Not Suitable	Less than 20 percent of MAT	All other combinations		5

Source: Land Resources Appraisal of Bangladesh, (UNDP-FAO, 1988)

Table 14. Relationship between agro-climatic, agro-edaphic and land suitability classification

Agro-climatic suitability rating	Agro-edaphic suitability rating	Land suitability rating
VS	S1	VS
	S2	S
	S3	MS
	S4	LS
	N	NS
S	S1	S
	S2	MS
	S3	LS
	S4	LS
	N	NS
MS	S1	MS
	S2	LS
	S3	LS
	S4	NS
	N	NS
LS	S1	LS
	S2	LS
	S3	NS
	S4	NS
	N	NS
NS	S1	NS
	S2	NS
	S3	NS
	S4	NS
	NS	NS

VS=Very Suitable, S=Suitable, MS=Moderately Suitable, LS=Marginally Suitable, NS=Not Suitable

3. Crop Suitability Maps

The outputs generated as maps for agro-edaphic suitability and agro-climatic suitability following the procedure mentioned in the section on Methodology. Significant variations with respect to spatial distributions for different crops have been observed from these maps. However, edaphic or land factors are more limiting than the agro-climatic factors. Agro-climatically, most parts of Bangladesh fall into suitable to moderately suitable categories for the selected crops.

After overlaying the agro-edaphic suitability map and agro-climatic suitability map and applying the overall suitability rules (Table 14), maps were generated delineating potentially suitable areas for 15 different crops.

Potentially suitable areas for rice (aus, aman, and boro), wheat, maize, potato, pulses (lentil, mungbean, and gram) oilseed crops (mustard and groundnut), spices (onion, garlic, and chili), jute, and sugarcane, are presented in Figures 24-38.

The niche for growing spices like onion and garlic is very similar. In other words, their soil, water and climatic requirements are almost identical. Therefore, these two crops were treated as one. One set of limitations was assigned for these crops.

The suitability maps of different crops have been prepared following the above procedures. The maps show the potential areas under different suitability class i.e. very suitable, suitable, moderately suitable, marginally suitable and not suitable. The crop suitability maps are prepared for rice (T. aus, T. aman, boro), wheat, maize, potato, lentil, mungbean/blackgram, gram (chickpea), mustard, groundnut, onion/garlic, chili.

The land resources data used for crop zoning is based on reconnaissance soil survey. In the recent years, agro-climatic conditions have been changing over the last decades due to global warming. More than 26% area has been affected by salinity compared to the areas in 1970. New polders have been developed through silt deposition in coastal region. SRDI has already collected recent information on soil salinity. The present crop zoning scenario will be changed upon incorporation of recent soil salinity data. It may happen that very suitable area may become suitable or moderately suitable for growing particular crop. It may also happen that non-suitable saline area may turn into moderately suitable or suitable with the introduction of salt tolerant crop variety and sustainable technology.

3.1. Rice

Rice is staple food in Bangladesh. It is cultivated on 11.35 Mha of land to produce 45.69 Mt paddy equivalents to 31.98 Mt milled rice. It provides food, generates income and employment. Rice ranks first position (occupying 93% of cereals) among the cereal crops. Rice is a major source of

livelihood in the country. It covers about 77% of the total cropped area. Bangladesh holds the fourth position among 16 Asian countries in terms of area and production of rice. Almost 90% of the population of Bangladesh, Myanmar, Sri Lanka, and Vietnam are rice consumers.

Most of the land in Bangladesh is suitable for rice cultivation. The production of rice grain requires more water than other cereals. Rice can be grown in a wide range of environments. Rice is extensively cultivated in warm climates. Rice is a tropical and sub-tropical plant, needing fairly high temperature with range from 20°-40°C. The optimum growth and development requires 30-32°C day-time temperature and 20°C night-time temperature. Sunlight is very essential for the development and growth of rice plant. The yield of rice is greatly influenced by solar radiation especially 35-45 days before ripening period. Prevalence of bright sunshine and low temperature at ripening period increases rice yield. It can be grown in all type of soils from light to heavy soil. Clay soil is the best for rice cultivation due to its high water holding capacity. Soil textures of silt clay and silt clay loam are also good for rice. However, very sandy soil is not suitable for rice cultivation due to low water holding capacity. Sandy soil requires more irrigation and thus cost of rice cultivation increases. Slightly acid soils with pH range from 6-7 are better for rice cultivation, but rice can be grown with pH range from 4-8. The cultivation methods of rice vary among seasonal changes.

Rice is the dominant crop cultivated throughout the year in Bangladesh. It is grown in three distinct rice growing seasons namely, `Aus' (April to August), `Aman' (July to November), and `Boro' (December to May). Transplanted aman is grown almost everywhere in Bangladesh under rainfed or with supplementary irrigation, while broadcast aman is mostly grown in the low-lying areas of the south and northeast. Boro is primarily grown under irrigated conditions, while aus are well scattered crop. The rain-fed rice crop consists of aus and aman groups. The rain-fed area is about 93-94% of the total area under aus and aman crops.

Aus rice, local and HYV are grown on 336,785 and 647,267 hectares of land to produce 3,93,434 and 1,316,127 tonnes respectively. The potential areas under different suitability class for aus rice are shown in Table 15 and Figure 24.

Aman rice, transplanted local, HYV and broadcast aman rice are grown on 1,414,180; 3,772,896 and 475,529 hectares of land to produce 2,236,737; 9,403,633 and 566,792 tonnes respectively. The potential areas under different suitability class for aman rice are shown in Table 16 and Figure 25.

Boro is the most important crop in Bangladesh for its huge production from transplanted local, HYV and Hybrid rice are grown on 107,329; 3,913,750 and 685,796 hectares of land to produce 214,550; 14,622,485 and 3,221,927 tonnes respectively. The potential areas under different suitability class for boro rice are shown in Table 17 and Figure 26.

Table 15. Areas under different suitability class for aus rice

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Aus Rice	Very Suitable (VS)	1,351,626	14%
	Suitable (S)	2,671,691	27%
	Moderately Suitable (MS)	2,612,170	27%
	Marginally Suitable (LS)	1,743,233	18%
	Not Suitable (NS)	1,426,639	15%
	VS+S	5,605,804	41%
	S+MS	3,415,782	54%
	VS+S+MS	2,014,139	68%

Table 16. Areas under different suitability class for aman rice

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Aman Rice	Very Suitable (VS)	3,701,517	38%
	Suitable (S)	1,904,287	19%
	Moderately Suitable (MS)	1,511,494	15%
	Marginally Suitable (LS)	502,645	5%
	Not Suitable (NS)	2,185,417	22%
	VS+S	5,605,804	57%
	S+MS	3,415,782	35%
	VS+S+MS	2,014,139	73%

Table 17. Areas under different suitability class for boro rice

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Boro Rice	Very Suitable (VS)	3,477,679	35%
	Suitable (S)	2,725,829	28%
	Moderately Suitable (MS)	1,076,882	11%
	Marginally Suitable (LS)	1,355,051	14%
	Not Suitable (NS)	1,169,920	12%
	VS+S	6,203,508	63%
	S+MS	3,802,711	39%
	VS+S+MS	2,431,932	74%

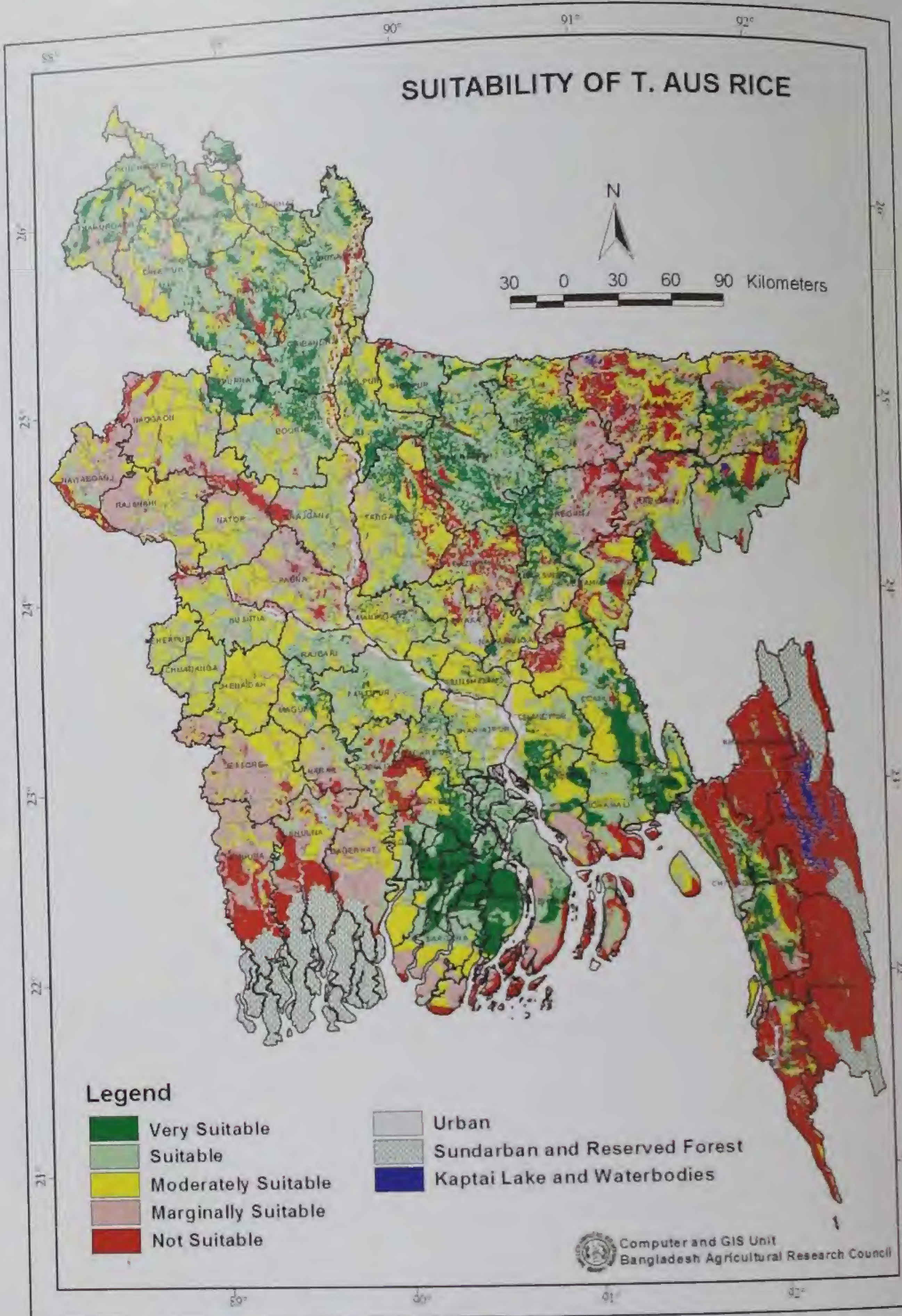

Figure 24. Potential Suitable Area for T. Aus

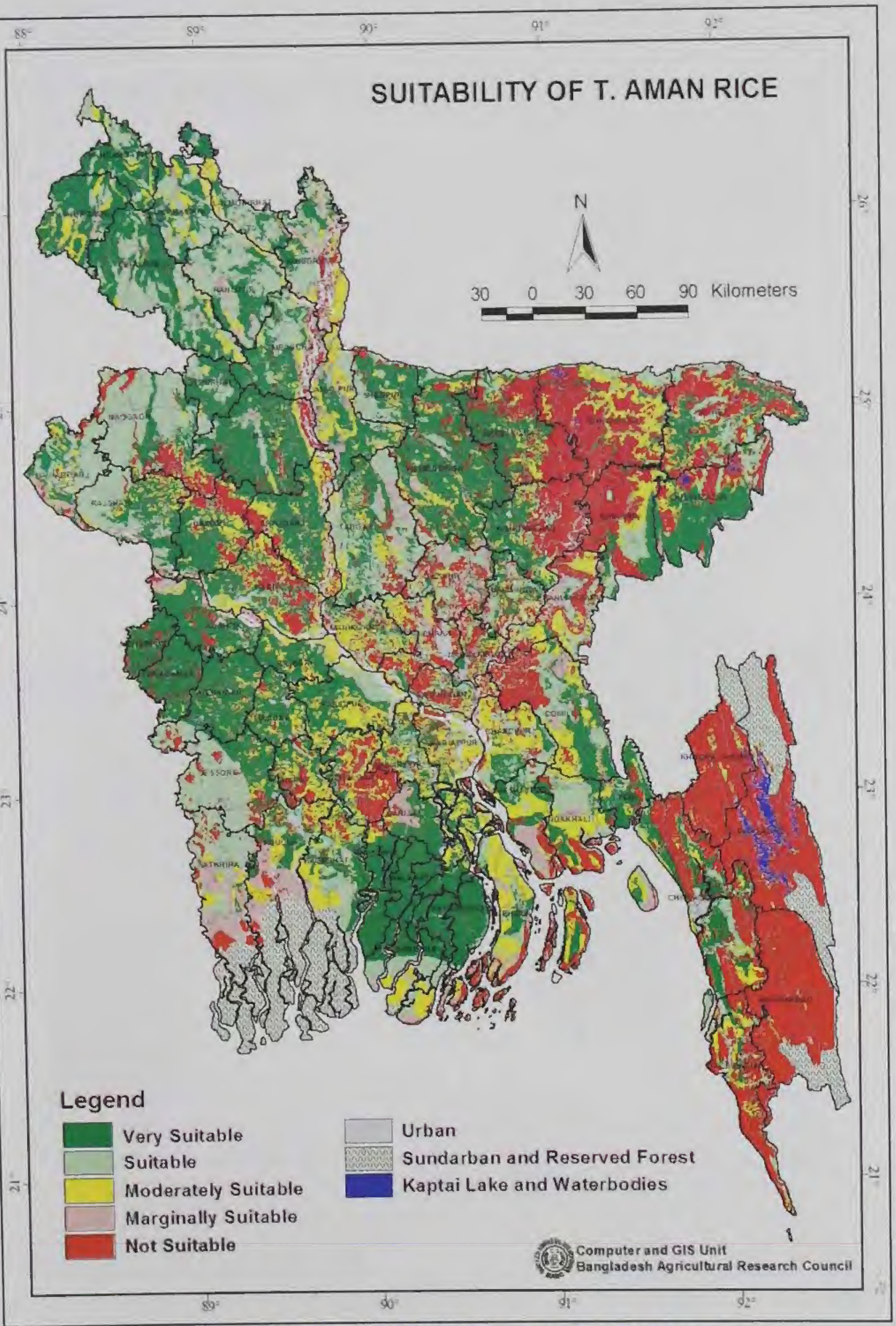

Figure 25. Potential Suitable Area for T. Aman

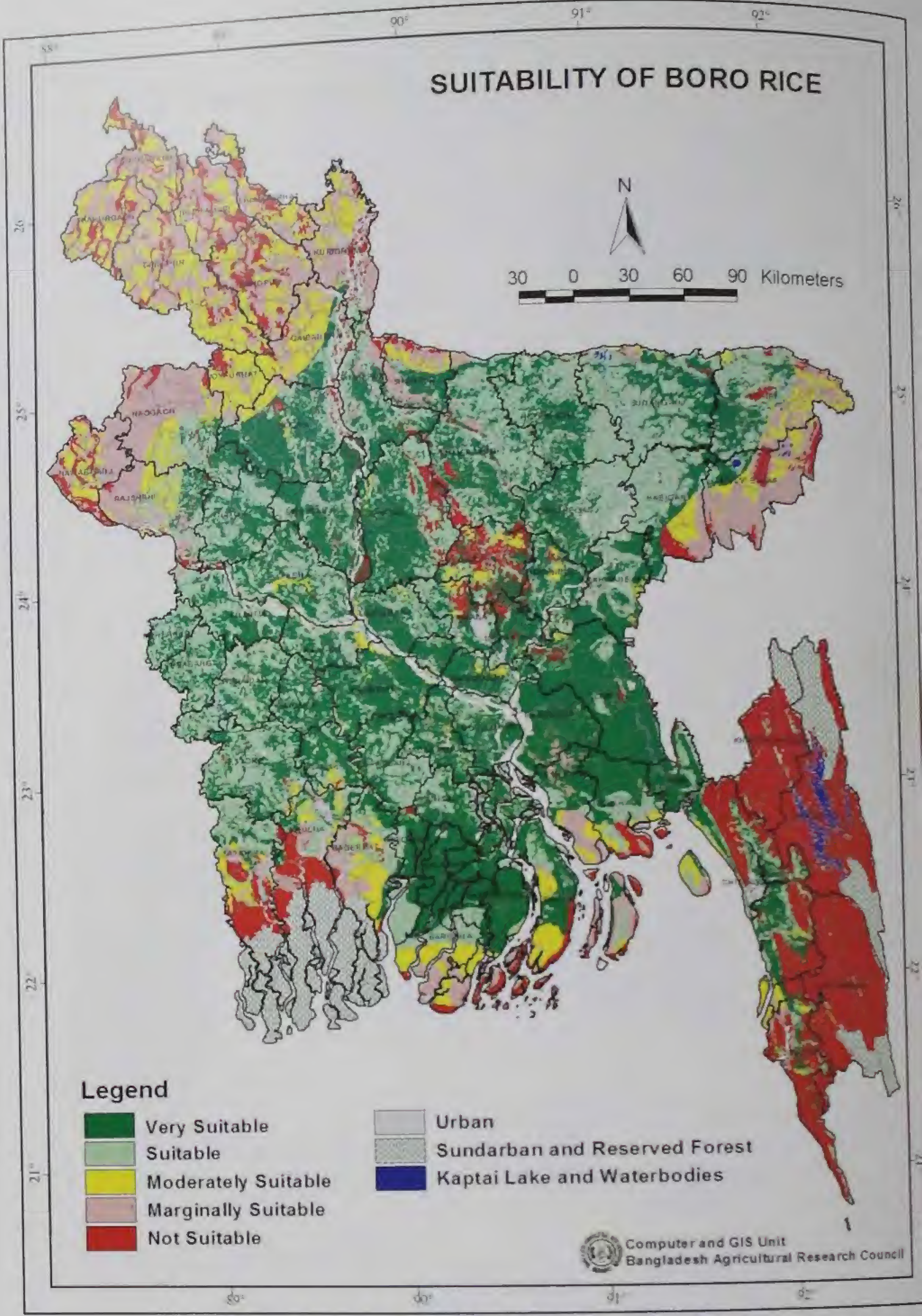

Figure 26. Potential Suitable Area for Boro

3.2. Wheat

More than 80% of wheat is grown in rice-wheat rotation of which about 50% is planted late. Late planting causes a significant yield loss in every year. Wheat is often late because of delayed harvesting of T. aman rice, longer time for land preparation, unavailability of labourers, late monsoon, and some cases excess moisture in soil, etc. Wheat is grown under a wide range of climatic and soil conditions. The optimum growing temperature is about 25°C. It favours low temperature between 20° and 30°C with minimum temperature of 3-4°C and maximum of 30-32°C. Well distributed rainfall ranging from 40-110 cm is optimum for wheat growth. Loam soil is the best for wheat cultivation. Clay loam and sandy loam soils can also be used. Wheat prefers dry soil with soil pH 6.4. In Bangladesh, it is a Rabi season crop, requiring dry weather and bright sunlight. The optimum sowing time is second week of November through first week of December. Depending on variety and weather conditions, 100-110 days are required from sowing to harvest.

The area of wheat is 3,76,256 ha with total production of 901,490 tonnes. The potential areas under different suitability class for wheat are shown in Table 18 and Figure 27.

Table 18. Areas under different suitability class for wheat

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Wheat	Very Suitable (VS)	1,327,944	14%
	Suitable (S)	3,513,872	36%
	Moderately Suitable (MS)	1,350,394	14%
	Marginally Suitable (LS)	1,075,097	11%
	Not Suitable (NS)	2,538,052	26%
	VS+S	4,841,817	49%
	S+MS	4,864,267	50%
	VS+S+MS	2,425,492	63%

3.3. Maize

Maize also known as corn, is an annual cereal. It is the third most important cereal crop in Bangladesh, after rice and wheat. It is a crop of tropical and sub-tropical regions. In Bangladesh, it can be cultivated in winter as rabi crop and in early summer seasons as Kharif-I crop. Maize can be grown from 10°-46°C but performs well in temperatures of 30-35°C and 460-600 mm rainfall. It can be grown well on a deep, moist, not to be heavy, well aerated loam soil. Sandy loam and heavy clay loam soils are suitable for maize cultivation. The crop is fairly acid tolerant and can be grown on soils with pH range between 4-9, but pH between 6-7 to be optimum for its growth. The optimum time of sowing is October- November in rabi season and mid February-March in Kharif-I season. Maize cultivation is increasing over the years. The area of maize is 1,52,000 ha with total production of 8,87,000 tonnes. The potential areas under different suitability class for maize are shown in Table 19 and Figure 28.

Table 19. Areas under different suitability class for maize

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Maize	Very Suitable (VS)	2,324,203	24%
	Suitable (S)	2,042,475	21%
	Moderately Suitable (MS)	1,523,634	16%
	Marginally Suitable (LS)	863,308	9%
	Not Suitable (NS)	3,051,741	31%
	VS+S	4,366,678	45%
	S+MS	3,566,108	36%
	VS+S+MS	5,890,312	60%

3.4. Potato

Potato is the fourth most important crop in Bangladesh. In the context of nutrient, potatoes are comparable with rice and wheat. Although potato is a temperate crop, it can be grown in most parts of the country during the winter months. Well-fertilized, sunny weather with sufficient soil moisture is appropriate for potato plantation. Potato is a cool season crop. It requires relatively mild temperature during early growth and cool weather during tuber formation. The optimum growth and development takes within 15-21°C. The growth rate decreases with the increase in temperature. However, foggy weather, high temperature and humidity could cause incidence of disease and insect pests. It is grown well in sandy loam and loam soils. Potatoes grow well on a wide variety of soils and soil pH can be as low as 5.0 with satisfactory production. Potatoes are less susceptible to scab disease when soil pH is 5.0-5.5. Potatoes (whole potato or cut potato) are planted in the first week of November in the northern region, but they are planted during mid November to end of November in southern region of the country. However, the climatic suitability is overridden by the edaphic suitability. Currently, potato is grown in about 434,562 hectares of land to produce 79,30,240 tonnes. The potential areas under different suitability class for potato are shown in Table 20 and Figure 29.

Table 20. Areas under different suitability class for potato

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Potato	Very Suitable (VS)	1,634,705	17%
	Suitable (S)	2,791,507	28%
	Moderately Suitable (MS)	2,487,864	25%
	Marginally Suitable (LS)	542,097	6%
	Not Suitable (NS)	2,349,188	24%
	VS+S	4,426,211	45%
	S+MS	5,279,370	54%
	VS+S+MS	6,914,075	71%

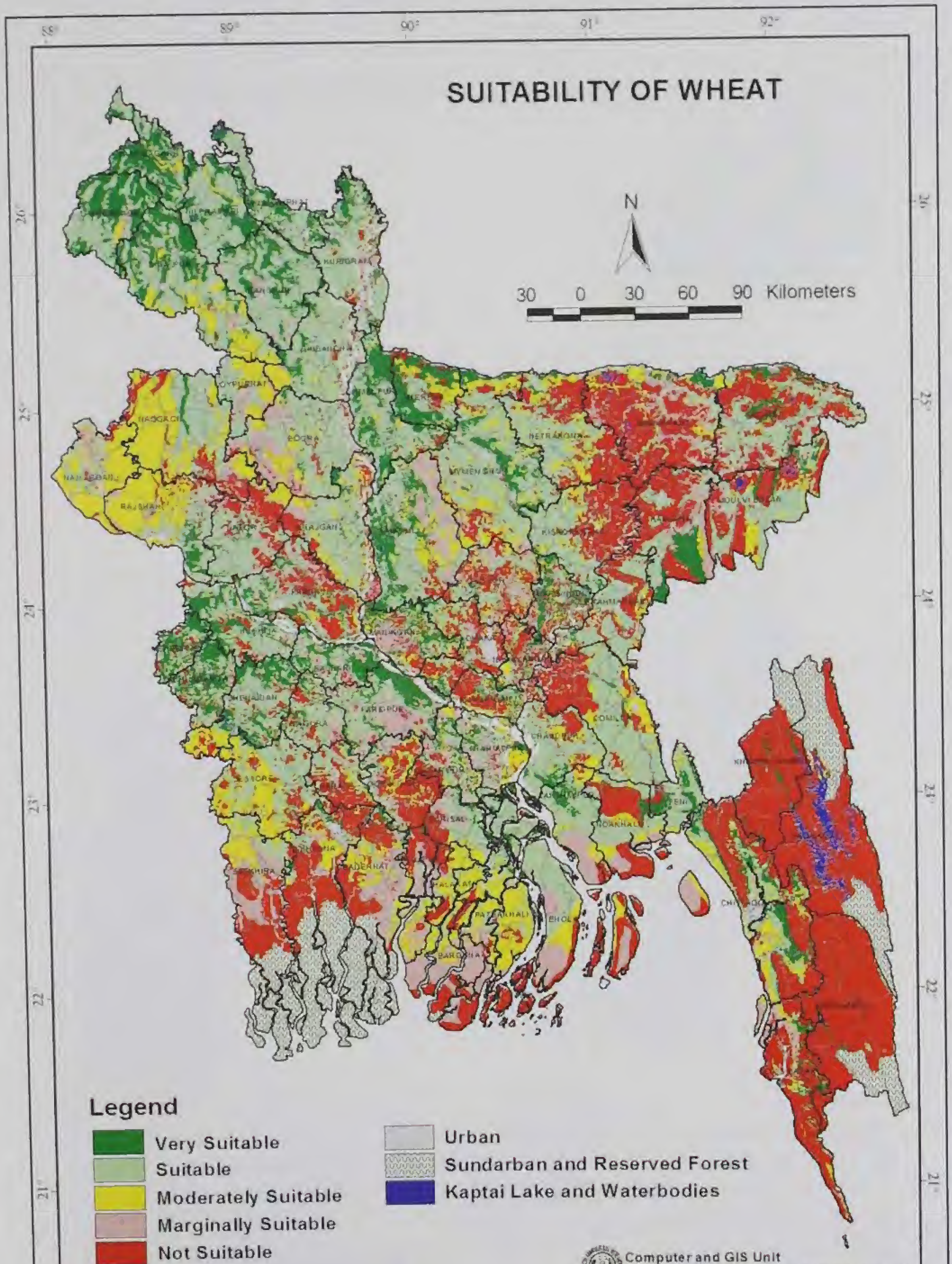

Figure 27. Potential Suitable Area for Wheat

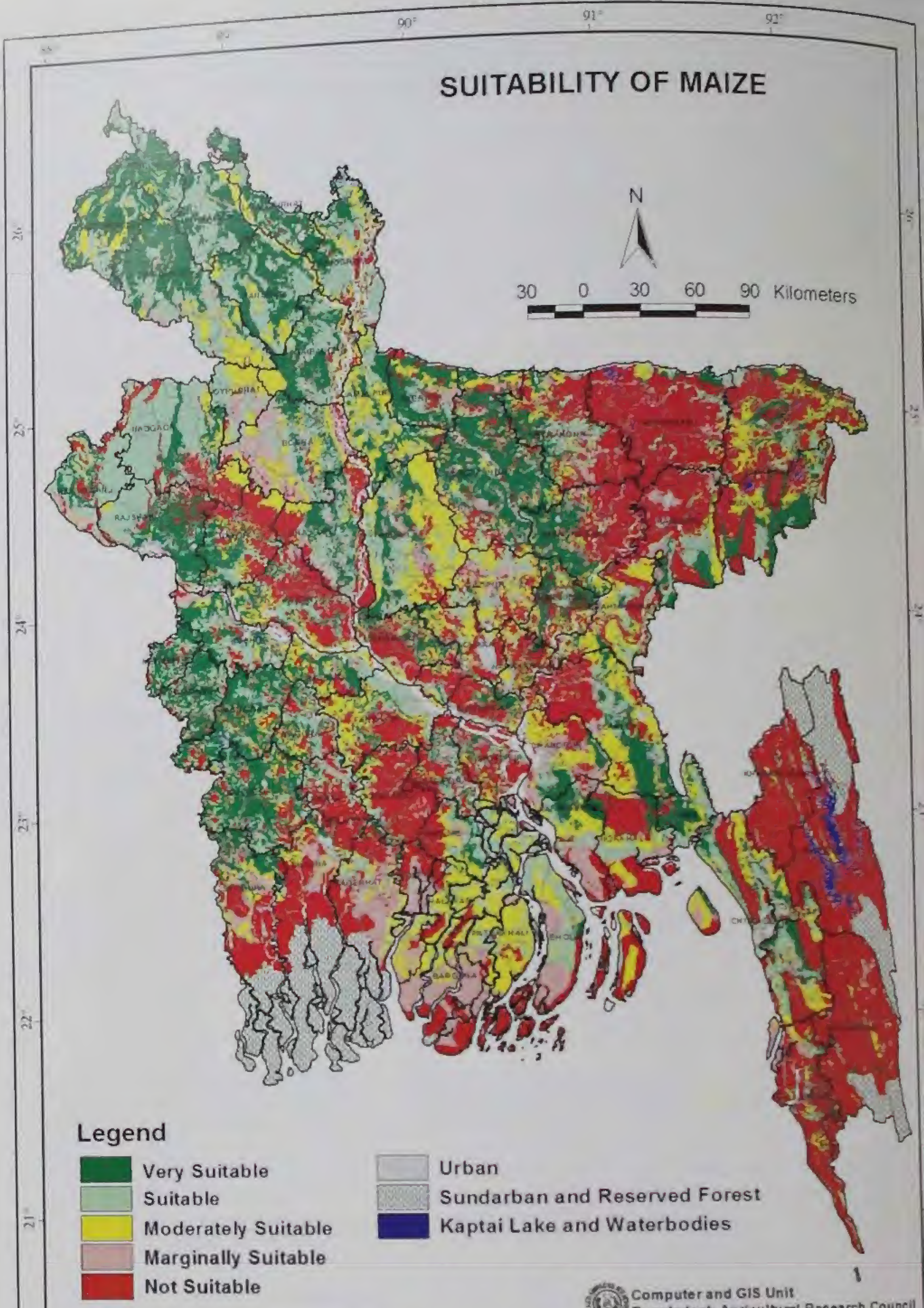

Figure 28. Potential Suitable Area for Maize

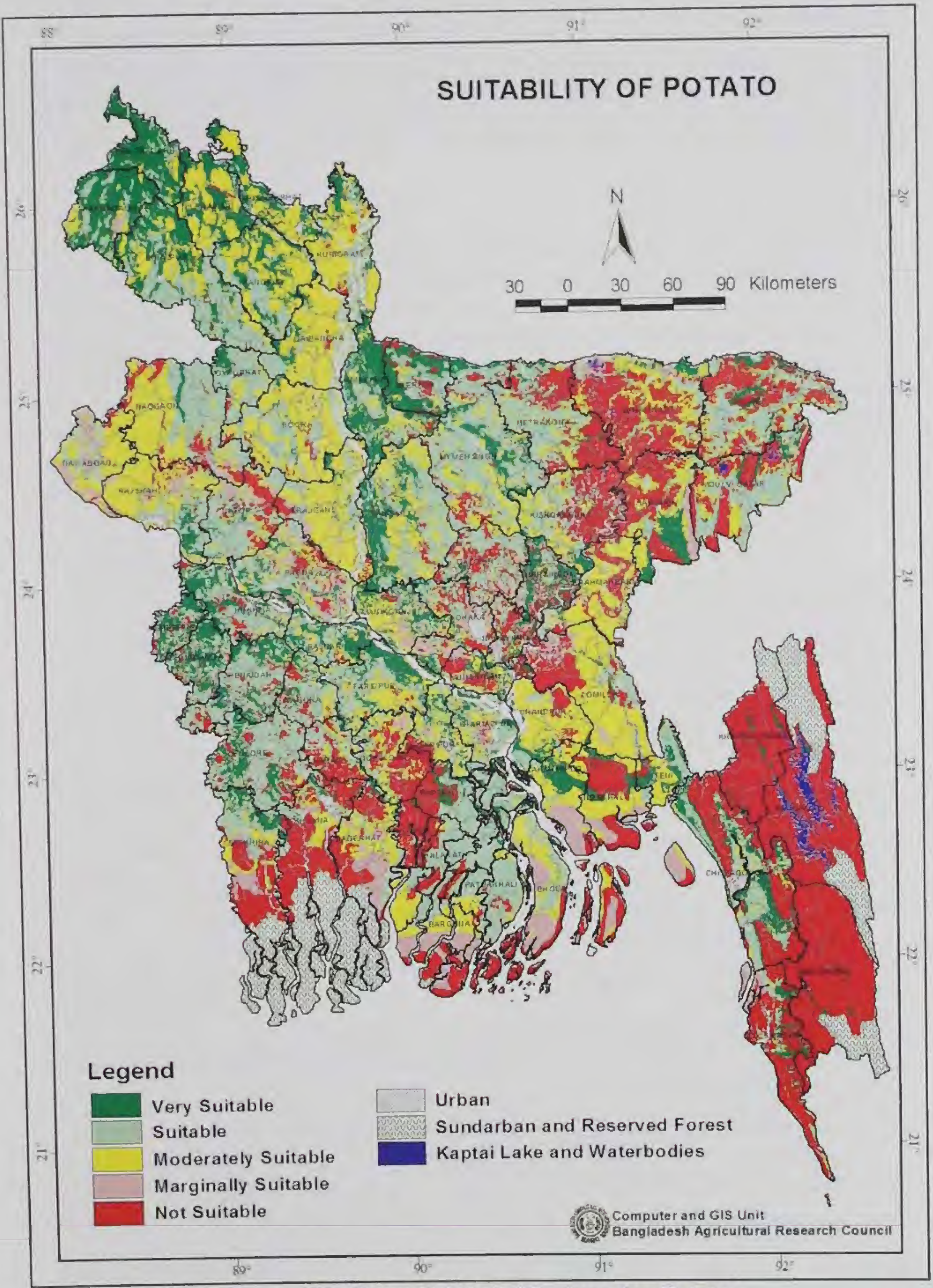

Figure 29. Potential Suitable Area for Potato

3.5. Pulses

Several types of pulses are grown and consumed in Bangladesh. It comprises of lentil, mungbean, gram, blackgram, grasspea, pea, cowpea and pegionpea. The area of pulse crops is 2,40,000 ha with total production 2,21,000 tonnes.

3.5.1. Lentil

Lentil is essentially a temperate crop but it is adapted to cooler regions of the sub-tropics. It is very suitable for production as sole crop and intercrop. In Bangladesh it is sown as rabi crop on residual soil moisture. Lentil is somewhat drought tolerant but susceptible to water-logging. Lentil prefers full sunny environments, loose, organic matter rich well-drained soil. It grows best in soil pH 6.0-6.5. Loam and clay loam soils are suitable for lentil cultivation. Lentil seeds germinate in 10 days at 20°C. The optimum sowing time is last week of October to first week of November. Its maturity varies from 95-150 days depending on the varieties and sowing time. Lentil also grow well in slightly acidic soils (pH 5.5-6.5)

The area of lentil is 77,000 ha with total production of 71,000 tonnes. The potential areas under different suitability class for lentil are shown in Table 21 and Figure 30.

3.5.2. Mungbean

Mungbean is important among all delicious pulses in Bangladesh. It ranks fifth among the pulses. It is a crop of the tropics and sub-tropics and requires a warm temperature regime. The optimum temperature ranges from 20°-35°C, depending upon season. Mungbean prefers medium highland and well-drained loamy soil and does not tolerate waterlogged condition. It prefers slightly acidic to neutral soil with pH 6.2-7.2. Mungbean is a full-sun crop which requires at least 6-8 hours sunlight per day. Mungbean is highly susceptible to weather damage. So, dry weather is needed for good harvest. The optimum sowing time for Kharif-I season is last February through mid March and for Kharif-II season is first August through last September. The crop could be grown as sole and intercrop. It is harvested within 70-90 DAS. Biomass could be used as green manure after taking pod. For a long time both mungbean and blackgram were considered as variants of the same species.

The area of mungbean is 23,000 ha with total production of 20,000 tonnes. The potential areas under different suitability class for mungbean are shown in Table 22 and Figure 31.

3.5,3. Blackgram

In terms of cropped area and production, blackgram ranks fourth among the pulses in Bangladesh. It is a tropical plant, resistant to high temperature. It is sensitive to cloudy weather and cannot tolerate frost. As

blackgram and mungbean are closely related, most of the climate, soil, irrigation etc. requirements are common. The optimum temperature range for growth is 27-30°C. Dry weather period is required at the time of harvest. Medium high and well-drained loam and clay loam soils are suitable. Blackgram prefers loam soils with pH 5.5-7.5.

It is widely cultivated in the north and north-western region of the country; especially in Chapai Nawabgonj district. Blackgram is a warm weather crop. It grows well in areas with an annual rainfall varying from 60-100 cm. Root growth can be restricted in heavy clays. Blackgram is more tolerant to waterlogged conditions than mungbean. The optimum sowing time for Kharif-I season is last February to mid March and for Kharif-II season is first August to last September. Crop sown in Kharif-I is harvested by end of May, but when sown in kharif-II is harvested by end of October. It matures within 90-110 DAS. Biomass is used as green manure to enhance soil fertility. The area of blackgram is 32,000 ha with total production of 28,000 tonnes. The potential areas under different suitability class for mungbean are shown in Table 22 and Figure 31.

3.5.4. Gram

Gram or chickpea is a temperate crop and well adapted to sub-tropical conditions. It is highly sensitive to excess moisture, high humidity and cloudy weather which affect its flowering and pod setting. Gram is a cool season annual crop and prefers diurnal cycle of cool (17.8°-21°C) nights and warm (21°-26.7°C) days. It cannot withstand heavy rains and does not grow well in wet regions.

Gram is suitable for production as sole crop and intercrop. Loam and clay loam soils are suitable for gram cultivation. They produce good yields in drier conditions because of their deep tap root. Excess moisture at the time of sowing may cause foot rot diseases. Short periods of waterlogged conditions reduce plant growth and cause root and stem rot disease. Therefore, good drainage is necessary. High yield and quality gram seeds are obtained from areas having lighter and well-distributed rainfall patterns.

Although gram can be grown on soils having pH range of 6.0-9.0, it is sensitive to salinity and alkalinity (Kay, 1979). Gram grows best in fertile sandy loam, well-drained soils. In most parts of the country, the optimum sowing time is November 20 to December 7 and for Barind region the optimum sowing time is last week of October to first week of November. Crop is harvested within 110-120 DAS.

The area of gram is 7,224 ha with total production of 5,744 tonnes. The potential areas under different suitability class for gram are shown in Table 23 and Figure 32.

Table 21. Areas under different suitability class for lentil

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Lentil	Very Suitable (VS)	1,940,123	20%
	Suitable (S)	1,945,587	20%
	Moderately Suitable (MS)	1,043,878	11%
	Marginally Suitable (LS)	692,554	7%
	Not Suitable (NS)	4,183,219	43%
	VS+S	3,885,710	40%
	S+MS	2,989,464	30%
	VS+S+MS	4,929,587	50%

Table 22. Areas under different suitability class for mungbean/blackgram

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Mungbean	Very Suitable (VS)	2,641,272	27%
	Suitable (S)	1,512,757	15%
	Moderately Suitable (MS)	2,527,246	26%
	Marginally Suitable (LS)	1,017,349	10%
	Not Suitable (NS)	2,106,733	21%
	VS+S	4,154,030	42%
	S+MS	4,040,004	41%
	VS+S+MS	6,681,277	68%

Table 23. Area under different suitability class for gram

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Gram	Very Suitable (VS)	2,416,271	25%
	Suitable (S)	1,960,237	20%
	Moderately Suitable (MS)	1,793,092	18%
	Marginally Suitable (LS)	1,000,038	10%
	Not Suitable (NS)	2,635,723	27%
	VS+S	4,376,508	45%
	S+MS	3,753,329	38%
	VS+S+MS	6,169,599	63%

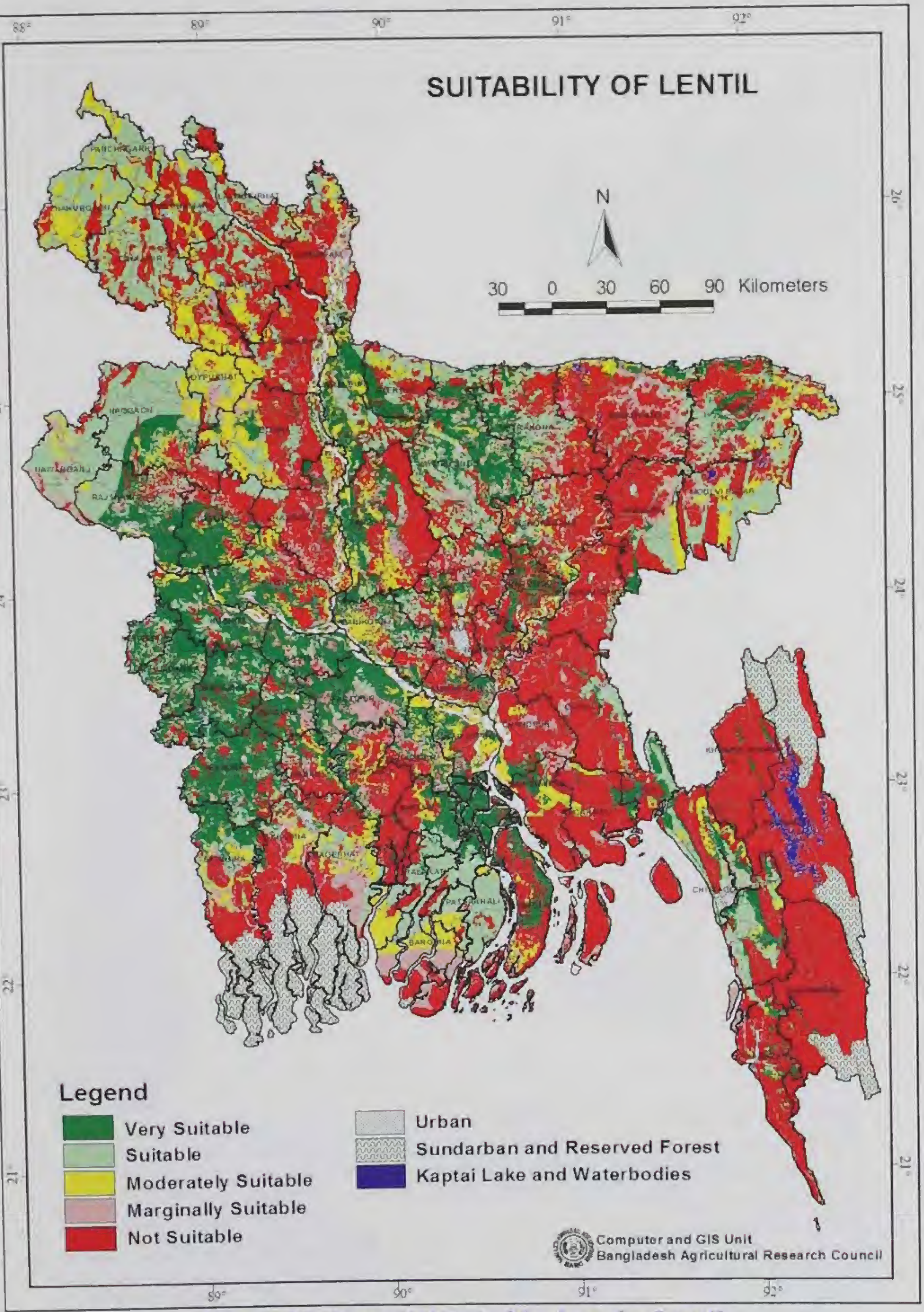

Figure 30. Potential Suitable Area for Lentil

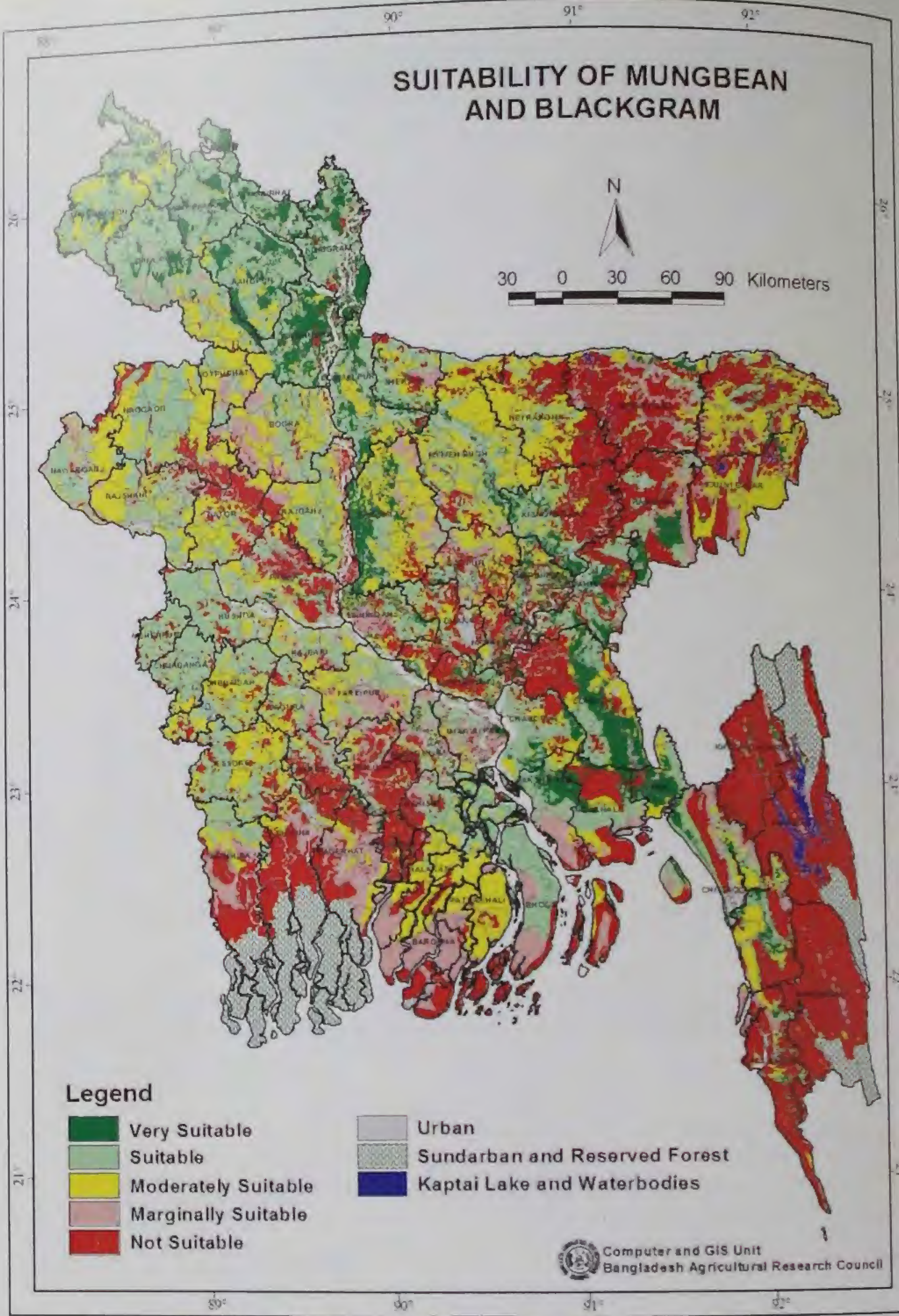

Figure 31. Potential Suitable Area for Mungbean/Blackgram

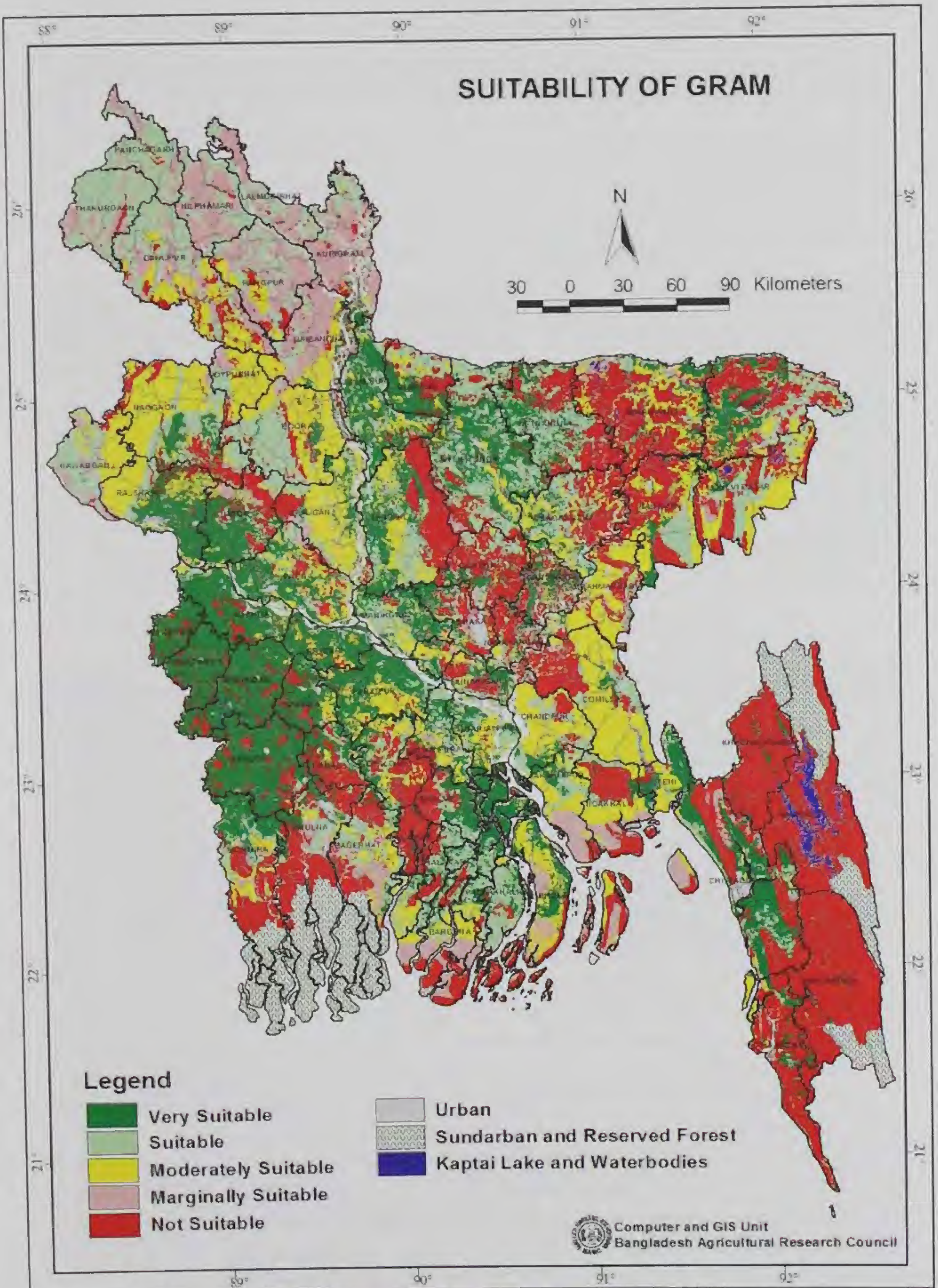

Figure 32. Potential Suitable Area for Gram

3.6. Oil seed crops

Oil seeds are important agricultural crops in Bangladesh. Among the oil seed crops, mustard, sesame, groundnut, sunflower and soybean are most common. The total area is 365,439 ha and production is 786,000 tonnes.

3.6.1. Mustard

Mustard is the main edible oil crop grown in Bangladesh. Mustard seed of different varieties contains 40-44% oil. Its oil cake contains 40% protein. Mustard grows well in cool and moist climate, it is a rabi crop in Bangladesh. It grows well within temperature range from 10°-20°C. In general, high temperatures (higher than 24-25°C) cause a sharp decline in oil content of seeds. The optimum sowing time is October to mid-November and grown well in mild winter regions. Seed germination may be slow if cool temperature prevails for longer period. Mustard prefers soil pH range of 5.5-6.8. The best soil for mustard is clay loam with good tilth, medium texture containing fairly high organic matter. It can also be grown well in loam and sandy loam soils. It is harvested within 70-100 DAS, depending upon variety.

The area of mustard is 242,000 ha with total production of 222,000 tonnes. The potential areas under different suitability class for mustard are shown in Table 24 and Figure 33.

3.6.2. Groundnut

Groundnut also known as peanut is a food crop. Apart from its food value, it is a major oilseed and fodder crop. Its seed contains 48-50% oil and 22-29% protein and produces high quality edible oil.

Climatic conditions such as temperature and rainfall significantly influence the groundnut production. Warm and moist conditions are very favourable than cool and wet climate. Temperature is a major environmental factor that determines the rate of crop development. Temperatures above 35°C inhibit the growth of groundnut. Optimum mean daily temperature for growth is 30°C and growth ceases at 15°C. Soil temperature above 21°C is needed for rapid emergence. The optimum temperature for the most rapid germination and seedling development is about 30°C. Adequate and well-distributed rainfall during the growing season, especially at flowering, pegging and pod formation stages, is essential for maximum yield and quality. Groundnut is grown in areas receiving rainfall 60-150 cm. The groundnut crop cannot withstand severe drought and water stagnation. Groundnut prefers an acidic soil (pH 5.1-6.5). It is grown well in sandy loam and loamy soil in char region. Soil should be soft enough so that peg of groundnut can be easily penetrated into soil. It gives higher yield in Rabi season. The optimum sowing time is mid October to mid November.

It fixes atmospheric nitrogen biologically and enriches the soil fertility for the succeeding crops. Some varieties can be cultivated in Kharif-I and Kharif-II seasons. Crop is harvested within 120-150 DAS, depending upon season and variety.

The areas of groundnut are 34,000 ha and production is 53,000 tonnes. The potential areas under different suitability class for groundnut are shown in Table 25 and Figure 34.

Table 24. Areas under different suitability class for mustard

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Mustard	Very Suitable (VS)	1,435,814	15%
	Suitable (S)	4,087,414	42%
	Moderately Suitable (MS)	1,353,053	14%
	Marginally Suitable (LS)	699,975	7%
	Not Suitable (NS)	2,229,104	23%
	VS+S	5,523,228	56%
	S+MS	5,440,467	55%
	VS+S+MS	6,876,281	70%

Table 25. Areas under different suitability class for groundnut

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Groundnut	Very Suitable (VS)	946,189	10%
	Suitable (S)	3,054,880	31%
	Moderately Suitable (MS)	2,118,720	22%
	Marginally Suitable (LS)	1,155,166	12%
	Not Suitable (NS)	2,530,405	26%
	VS+S	4,001,068	41%
	S+MS	5,173,600	53%
	VS+S+MS	6,119,789	62%

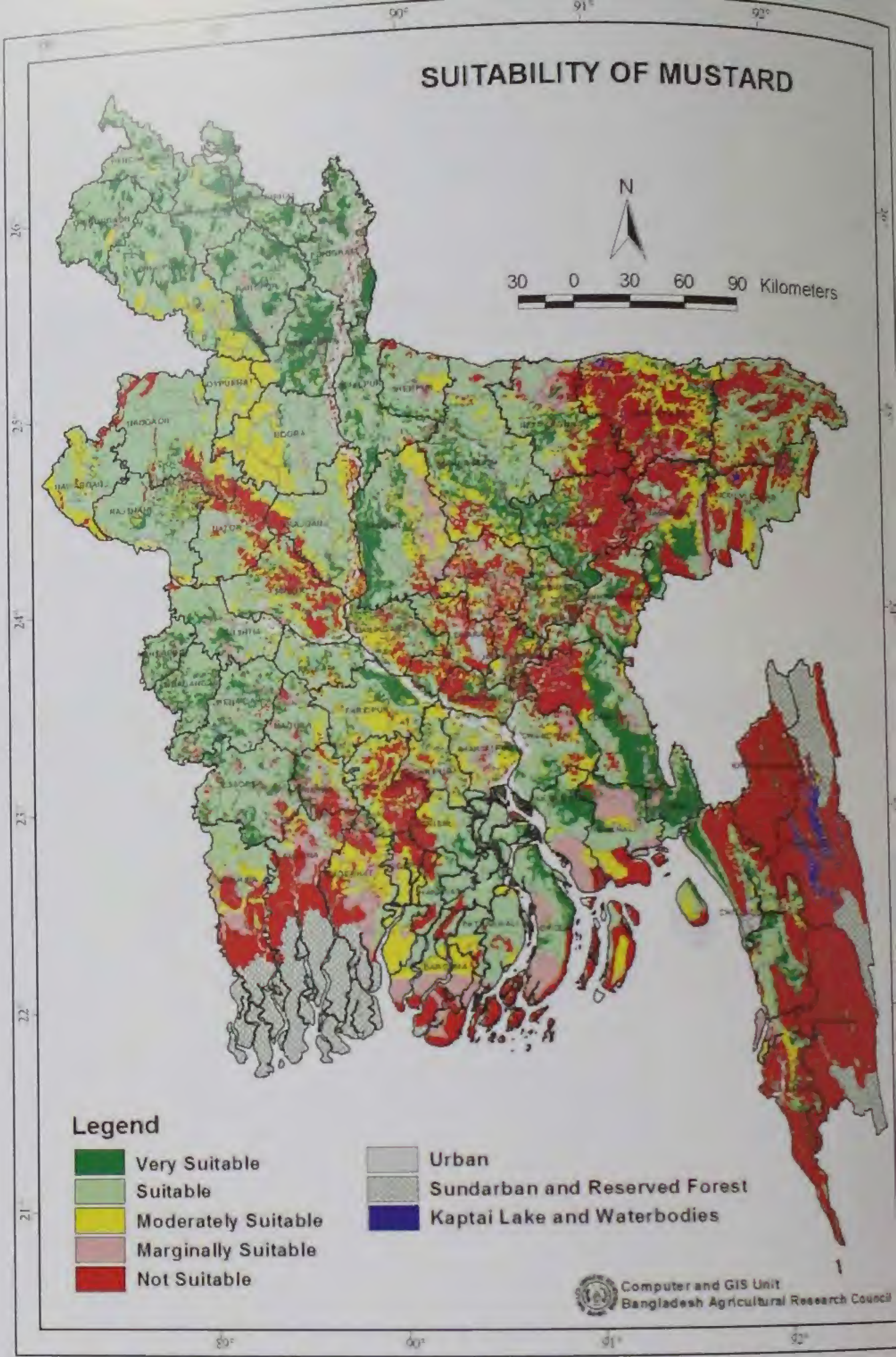

Figure 33. Potential Suitable Area for Mustard

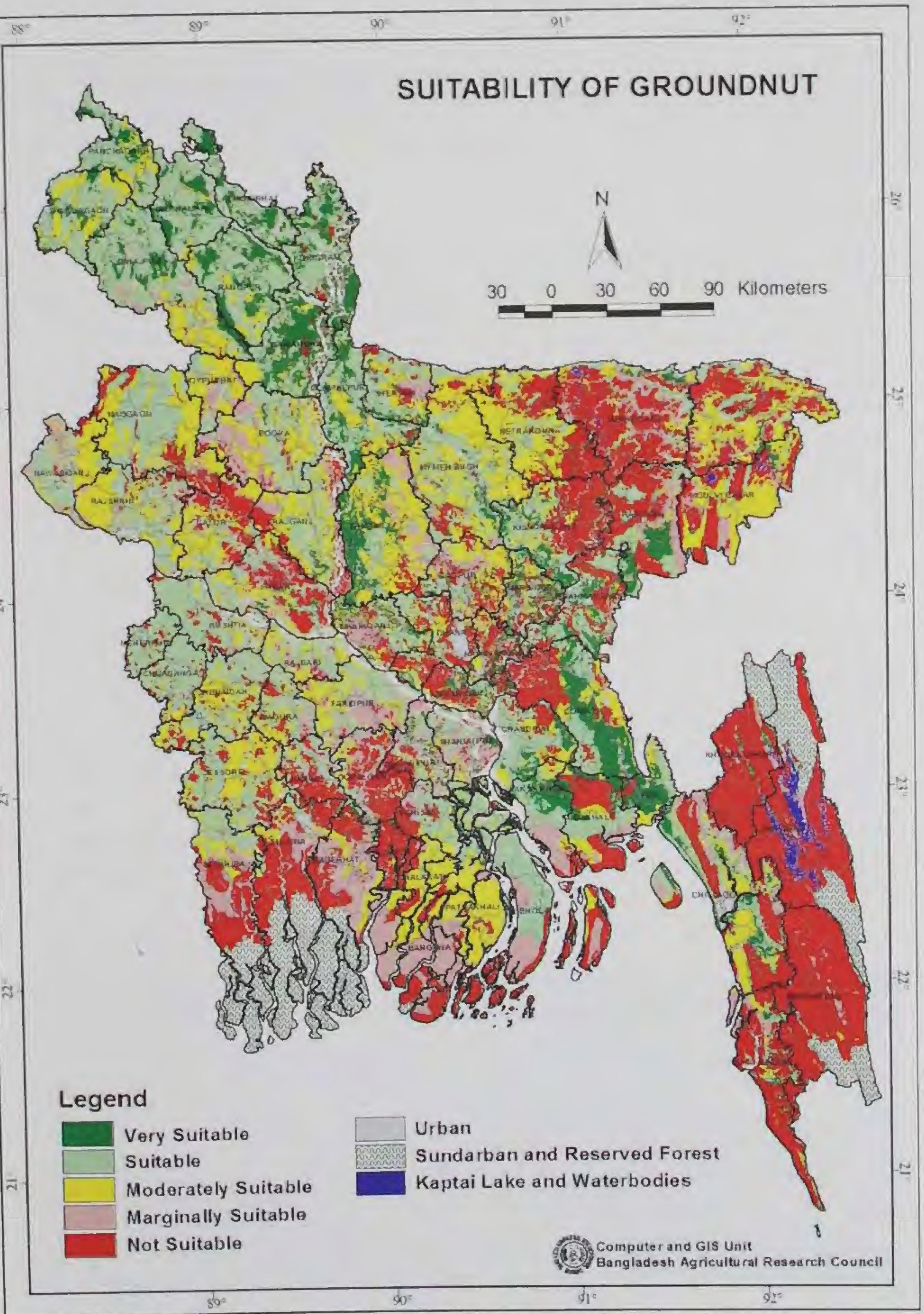

Figure 34. Potential Suitable Area for Groundnut

3.7. Spice crops

The major spice crops in Bangladesh are onion, garlic, coriander, chili, turmeric and ginger. The area of spice crops is 4,85,000 hectare with total production 2,293,000 tonnes. Spice crops have both nutritional and medicinal values.

3.7.1 Chili

Chili is an important cash crop in Bangladesh. It is regarded as main spice crop in the country. Capsaicin of chili is responsible for its pungency. It has demands at both green and ripe (dry) conditions. Green chili is rich in vitamin C. It has medicinal properties as well. Warm and moist weather is suitable for plant growth but dry weather is suitable for fruit growth. Chili plants grow best in a well-drained porous soil. The soil should be rich in organic matter and poor in clay content. The soil pH should be within 5.5-6.8. Sufficient water should be available with good drainage facilities. Shade free and well drained land is required. Sandy loams to clay loam soils are suitable. But organic matter rich loam soils are best for chili. It is cultivated in both Rabi and Kharif seasons, but capsicum (sweet chili) is grown in Rabi season only. The optimum sowing time is October-November for Rabi season and first week of February to March for Kharif-I season. In cropping season, fruits can be harvested 6-8 times.

Chili is grown all year round as green pepper, but there are two distinct seasons (rabi and kharif) when it is grown as a spice. It cannot withstand flooding therefore the land suitability for the cultivation of chili decreases drastically

The areas of chili is 87,000 ha with total production of 1,09,000 tonnes. The potential areas under different suitability class for chili are shown in Table 26 and Figure 35.

Table 26. Areas under different suitability slass for chili

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Chili	Very Suitable (VS)	946,189	10%
	Suitable (S)	3,054,880	31%
	Moderately Suitable (MS)	2,118,720	22%
	Marginally Suitable (LS)	1,155,166	12%
	Not Suitable (NS)	2,530,405	26%
	VS+S	4,001,068	41%
	S+MS	5,173,600	53%
	VS+S+MS	6,119,789	62%

3.7.2. Onion

Onion is mainly used as spice in Bangladesh. Onion ranks second among the spice crops in terms of production. In addition to nutritional values, it has a medicinal value. Cold weather is suitable for onion. Onion grows well at the temperature of 15°-25°C. Onions grow best in loose, well-drained soil with high fertility and sufficient organic matter. Loam and sandy loam soils are suitable for onion cultivation. Onions are sensitive to highly acid soils and grow best where the soil pH is 6.2-6.8. After irrigations, soil needs to be mulched so that bulb can grow well. Good drainage system is required especially for Kharif crop, as onion cannot tolerate water stagnancy. Basically onion is sown in December as rabi crop but some variety is grown in Kharif-I and II seasons. It matures within 50-70 DAS (seedling to maturity) and 110-120 DAS (bulb to bulb).

The area of onion is 1,18,000 ha with total production of 8,72,000 tonnes. The potential areas under different suitability class for onion are shown in Table 27 and Figure 36.

3.7.3. Garlic

Garlic is a notable cash crop in Bangladesh. It has many medicinal properties. It contains non-protein amino acid, which reduces human body cholesterol. Besides, garlic juice is used as insecticide, bio-fungicide, adhesive and anti-bacterial material. Garlic is used as remedy of stomach ailment, dysentery, typhoid, cholera and lung diseases. It is used to prepare jam, jelly, pickles, etc. It is cultivated in winter season. Garlic requires temperature of 15-25°C for suitable cultivation. Cold and fog-free weather conditions are required for proper plant growth and longer dry days are required for maturation of bulbs. The optimum sowing time is mid October through first week of November. High rainfall and excess moisture are harmful to garlic. Organic matter rich loam soil is best for garlic. Fertile soil, irrigation and drainage facilities are required. Garlic is grown well where soil pH 6-7. Sandy, high alkaline and saline soils are not suitable for garlic production. Weed free, loose and plain land is required. The optimum sowing time is mid October and harvested when leaves turns into yellow to brown colour.

The niche for growing spices like onion and garlic is very similar. In other words, their soil, water and climatic requirements are almost identical. Therefore, these two crops were treated as one. One set of limitations was assigned for these crops.

The area of garlic is 37,000 ha with total production of 164,000 tonnes. The potential areas under different suitability class for garlic are also shown in Table 27 and Figure 36.

Table 27. Areas under different suitability class for onion/garlic

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Onion/garlic	Very Suitable (VS)	477,903	5%
	Suitable (S)	2,831,867	29%
	Moderately Suitable (MS)	2,839,082	29%
	Marginally Suitable (LS)	1,279,552	13%
	Not Suitable (NS)	2,376,957	24%
	VS+S	3,309,770	34%
	S+MS	5,670,949	58%
	VS+S+MS	6,148,852	63%

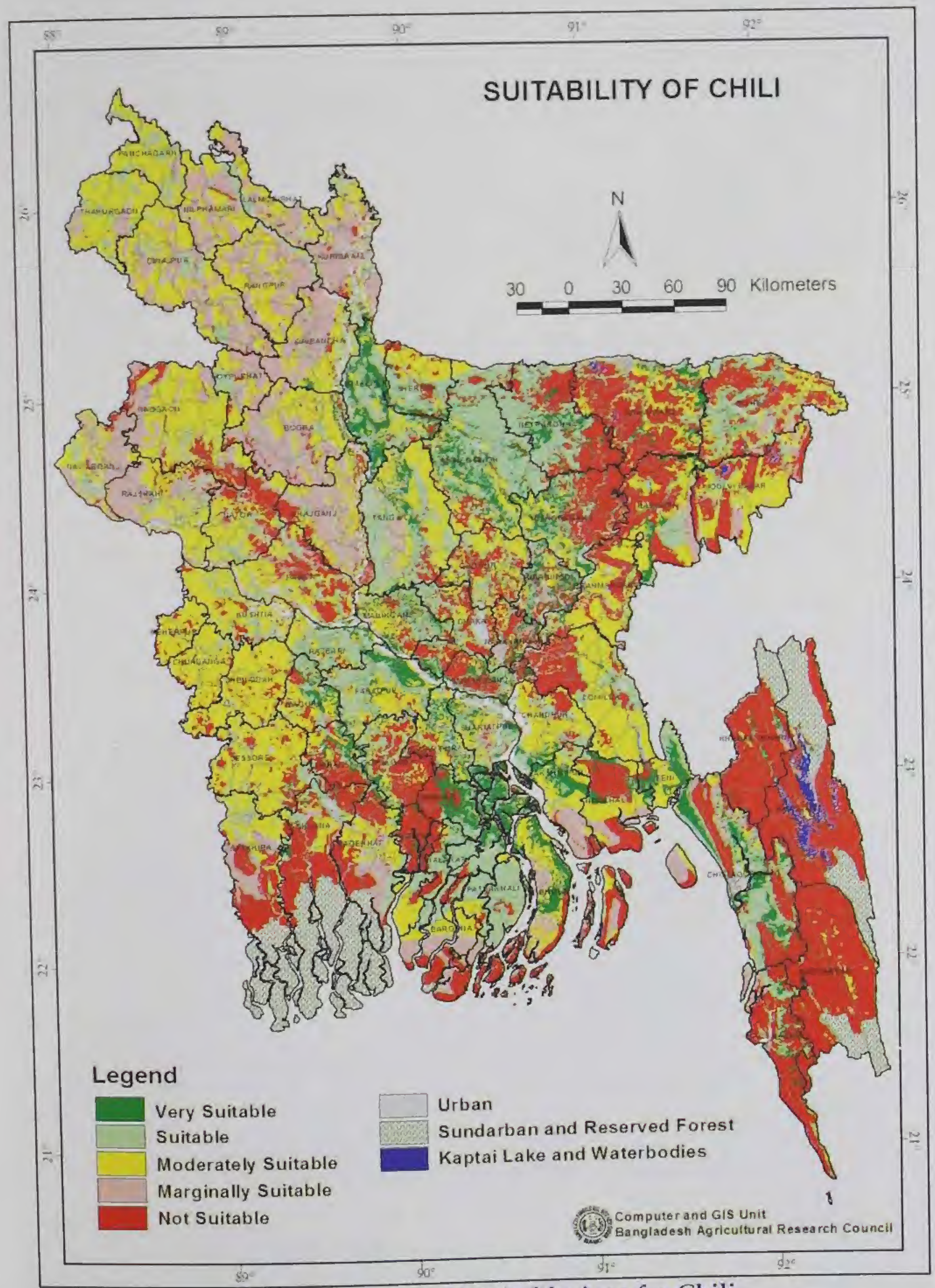

Figure 35. Potential Suitable Area for Chili

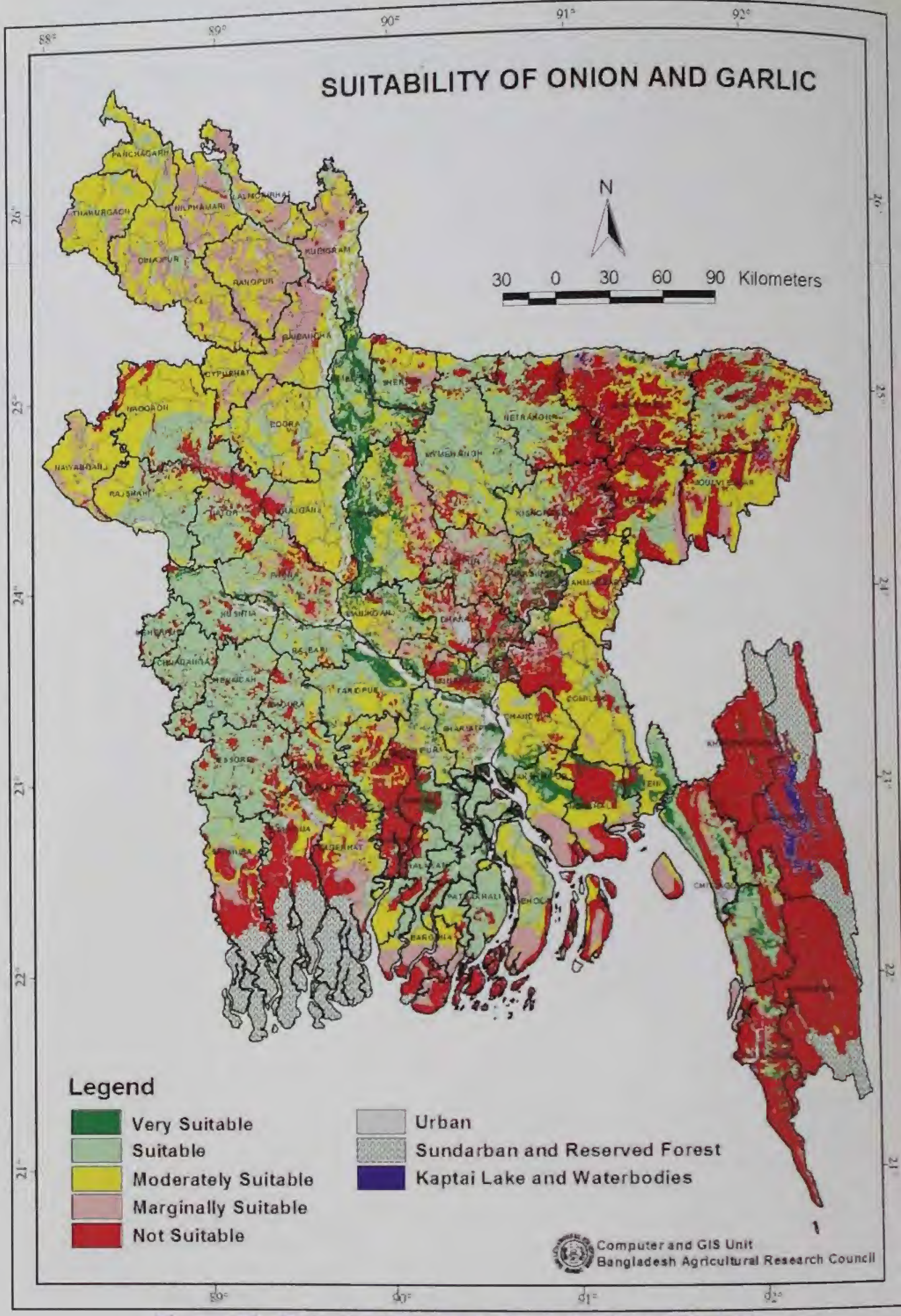

Figure 36. Potential Suitable Area for Onion/Garlic

3.8. Sugarcane

Sugarcane is one of the major cash-cum-industrial crops in Bangladesh. Sugar and gur are produced from the juice of the sugarcane. Around 70-75 lakh tons sugarcane are produced from 1.60-1.80 lakh hectare land and 1.50-2.00 lakh tons sugar and 3.50-4.00 lakh tons gur are extracted. According to the recommendations of Food and Agriculture Organization (FAO), at least 10 kg sugar and 3 kg gur should be consumed per person per day. Based on the recommendation, 13-14 lakh tons sugar and 4.02 lakh tons gur are required in the country.

High and medium high lands with no water-logging conditions are suitable for sugarcane cultivation. It is grown well in loam, sandy-loam and clay-loam soils. But sandy soil is not suitable for sugarcane cultivation. Optimum temperature is 30-40°C and rainfall 1100-1500 mm for better growth and yield of sugarcane. Adequate sunlight and soil moisture are also essential. Sugarcane is a long duration crop; planting to harvesting requires 12-14 months time. November is suitable month for sugarcane plantation. Average yield per hectare is 46.00 tons, but up to 100.00 tons yield can be achieved through proper management. In case of early plantation two intercrops can be grown in sugarcane field. Potato and mungbean are successfully grown as first and second intercrop respectively. Although large areas under suitable and moderately suitable classes have been shown in the map (Figure 37 and Table 28) but in reality, very little areas of 118,000 ha is cultivated to produce about 4,491,000 tonnes of sugarcane. This is primarily due to dominance of rice based cropping patterns and unavailability of land for sugarcane cultivation.

Table 28. Areas under different suitability class for sugarcane

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Sugarcane	Very Suitable (VS)	272,762	3%
	Suitable (S)	2,439,489	25%
	Moderately Suitable (MS)	1,443,896	15%
	Marginally Suitable (LS)	1,367,384	14%
	Not Suitable (NS)	4,281,829	44%
	VS+S	2,712,251	28%
	S+MS	3,883,385	40%
	VS+S+MS	4,156,147	42%

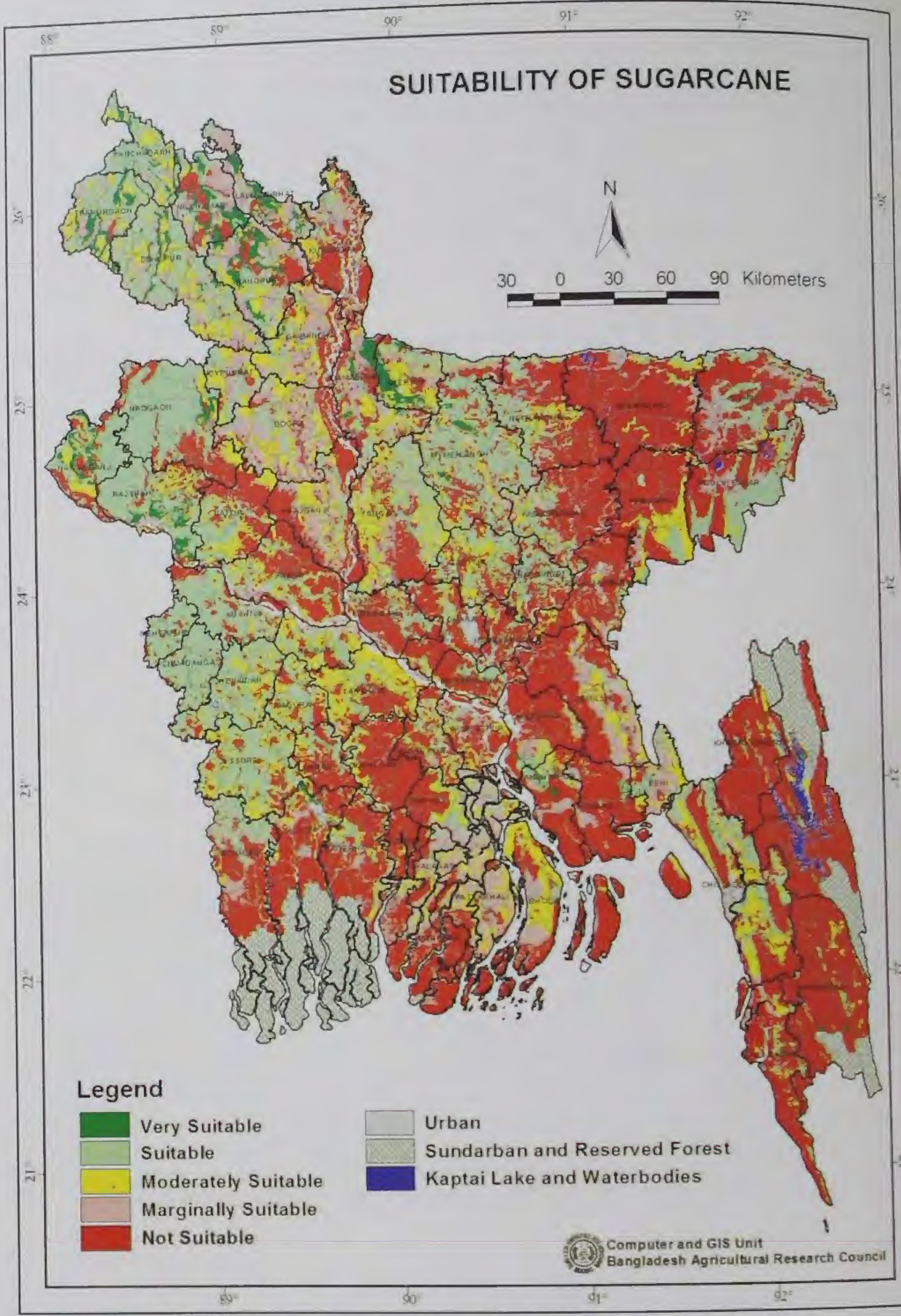

Figure 37. Potential Suitable Area for Sugarcane

3.9. Jute

Bangladesh ranks second among the jute growing countries. Jute, a major cash crop, accounts for about 6% of export earnings. The crop is a versatile and environmental friendly bio-degradable natural fiber. During 1971-72 about 678,200 hectares were under jute cultivation but currently the area has dropped to 4,16,431 ha. The present production is 5,090,000 bales or 916,200 tonnes (1 bale = 180 kg).

The climate, soil, and growing season influence jute cultivation. Jute requires warm and humid climate with the optimum temperature ranging from 24°-38°C, relative humidity from 70-80% and soil pH from 5.0-8.6. Adequate rainfall from 5-7.5 cm is required during sowing period and at weekly intervals after seedling emergence. Constant rain or water-logging is harmful. Sandy loam, silty loam and clay loam soils are suitable for growing jute. Jute is a Kharif-I season crop, sown in March to May based on rainfall, land types and varieties. Deshi or white jute and tossa or dark jute (C. olitorius) are mainly grown in the country. Deshi jute varieties are sown in March 20 to April 15 and harvested 110 DAS. Tossa jute varieties are sown in March 15 to May 15 and harvested 100 DAS. Jute is harvested during June to September.

The potential areas under different suitability class for jute are shown in Table 29 and Figure 38.

Table 29. Areas under different suitability class for jute

Crops	Suitability Class	Hectares	Percent of Cultivable Area
Jute	Very Suitable (VS)	1,406,953	14%
	Suitable (S)	4,126,332	42%
	Moderately Suitable (MS)	1,398,219	14%
	Marginally Suitable (LS)	729,602	7%
	Not Suitable (NS)	2,144,254	22%
	VS+S	5,533,286	56%
	S+MS	5,524,551	56%
	VS+S+MS	6,931,504	71%

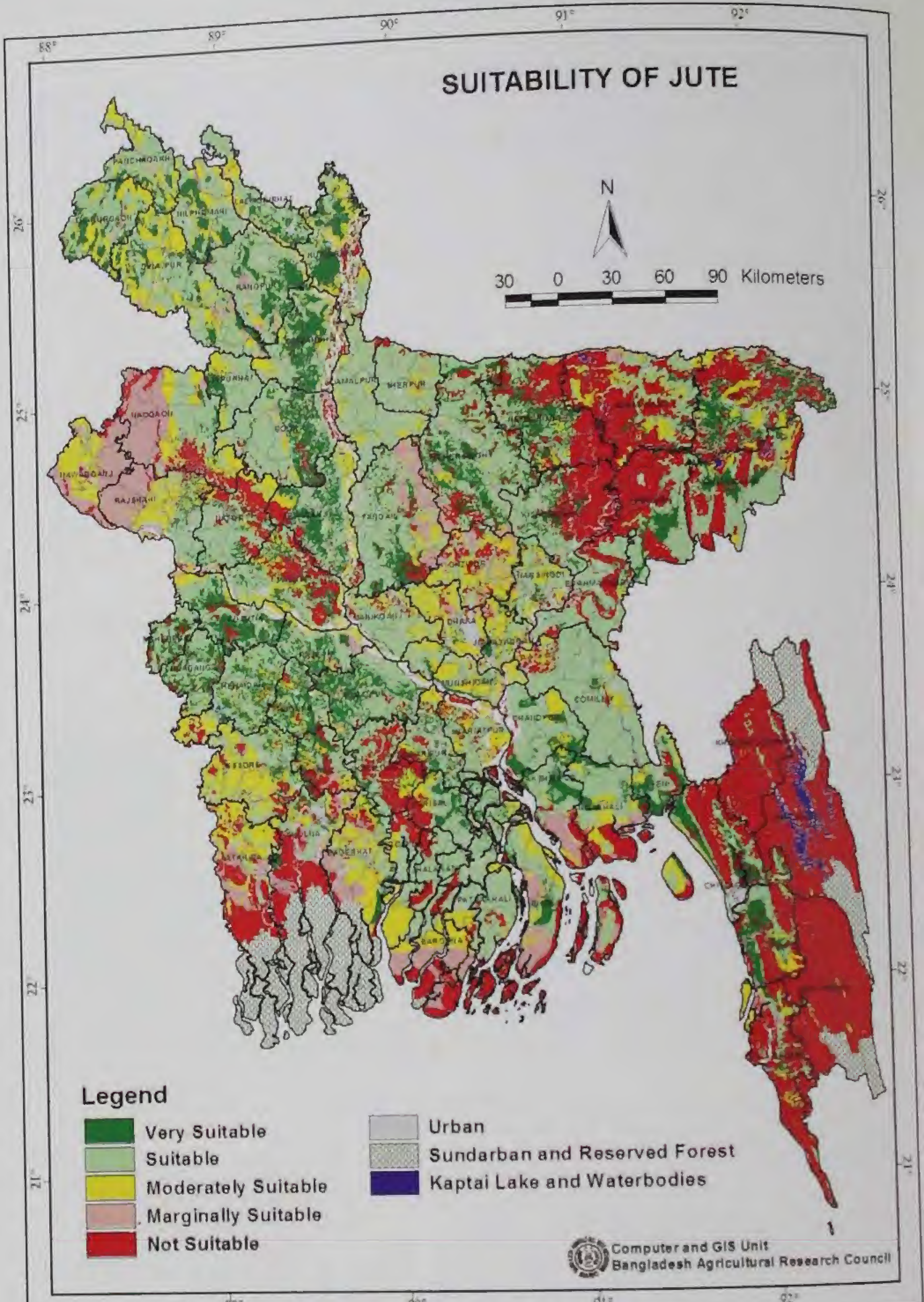

Figure 38. Potential Suitable Area for Jute

4. Crop Zoning

The cartographic model presented in Figure 23 summarized the processes involved in determining the agro-edaphic, agro-climatic and overall suitability of the selected crops. Finally the crop zoning maps were generated based on the criteria stated below.

The suitability maps of different crops have been prepared following the procedures described earlier in section 2. The maps show the potential areas under different suitability class i.e. very suitable, suitable, moderately suitable, marginally suitable and not suitable. The crops are rice (T. aus, T. aman, boro), wheat, kharif maize, potato, lentil, mungbean/blackgram, gram (chickpea), mustard, ground nut, chilli, onion/garlic, sugarcane and jute.

Based on the criteria given below, upazila-wise crop zoning maps generated for the selected crops are shown in Figures 39 to 53. The Upazila-wise area coverages of these crops in different suitability categories were generated. A sample output of boro rice crop is shown in Appendix-13.

4.1. Criteria for Crop Zoning

The percentage of the total cultivable areas of the upazila under each overall crop suitability class calculated earlier was used for crop zoning. Three categories of overall suitability viz., VS (Very Suitable), S (Suitable) and MS (Moderately Suitable) were considered for crop zoning. In classifying the crop zones the following criteria were used:

If the crop suitability classes VS+S ≥70 % of the total cultivable areas of the upazila (TCAU) and also the Sum of VS+S+MS ≥70% of TCAU then the upazila will be rated as S (Suitable).

If the crop suitability classes VS+S =60% of the TCAU and also the Sum of VS+S+MS ≥70% of TCAU then the upazila will be rated as MS (Moderately Suitable).

If the crop suitability classes VS+S =50% of the TCAU and also the Sum of VS+S+MS ≥70% of TCAU then the upazila will be rated as MS.

If the crop suitability classes VS+S =40% of the TCAU and also the Sum of VS+S+MS ≥70% of TCAU then the upazila will be rated as MS.

If the crop suitability classes VS+S =30% of the TCAU and also the Sum of VS+S+MS ≥70% of TCAU then the upazila will be rated as MS.

If the crop suitability classes VS+S =20% of the TCAU and also the Sum of VS+S+MS ≥70% of TCAU then the upazila will be rated as MS.

If the crop suitability classes MS ≥70% of the TCAU and also the Sum of VS+S ≤10% of TCAU then the upazila will be rated as MS.

If the crop suitability classes VS+S ≥50% of the TCAU and also the Sum of VS+S+MS ≤60% of TCAU then the upazila will be rated as LS.

If the crop suitability classes VS+S ≤40% of the TCAU and also the Sum of VS+S+MS =60% of TCAU then the upazila will be rated as LS.

If the crop suitability classes MS =60% of the TCAU and also the Sum of VS+S =10% of TCAU then the upazila will be rated as LS.

If the crop suitability classes VS+S ≤40% of the TCAU and also the Sum of VS+S+MS ≤60% of TCAU then the upazila will be rated as NS.

Using the above classification criteria crop zoning as S= Suitable Zone, MS= Moderately Suitable Zone, LS= Less Suitable Zone and NS = Not Suitable Zone was done and delineated on the maps. This provides the opportunity to grow the selected crops in different zones according to suitability.

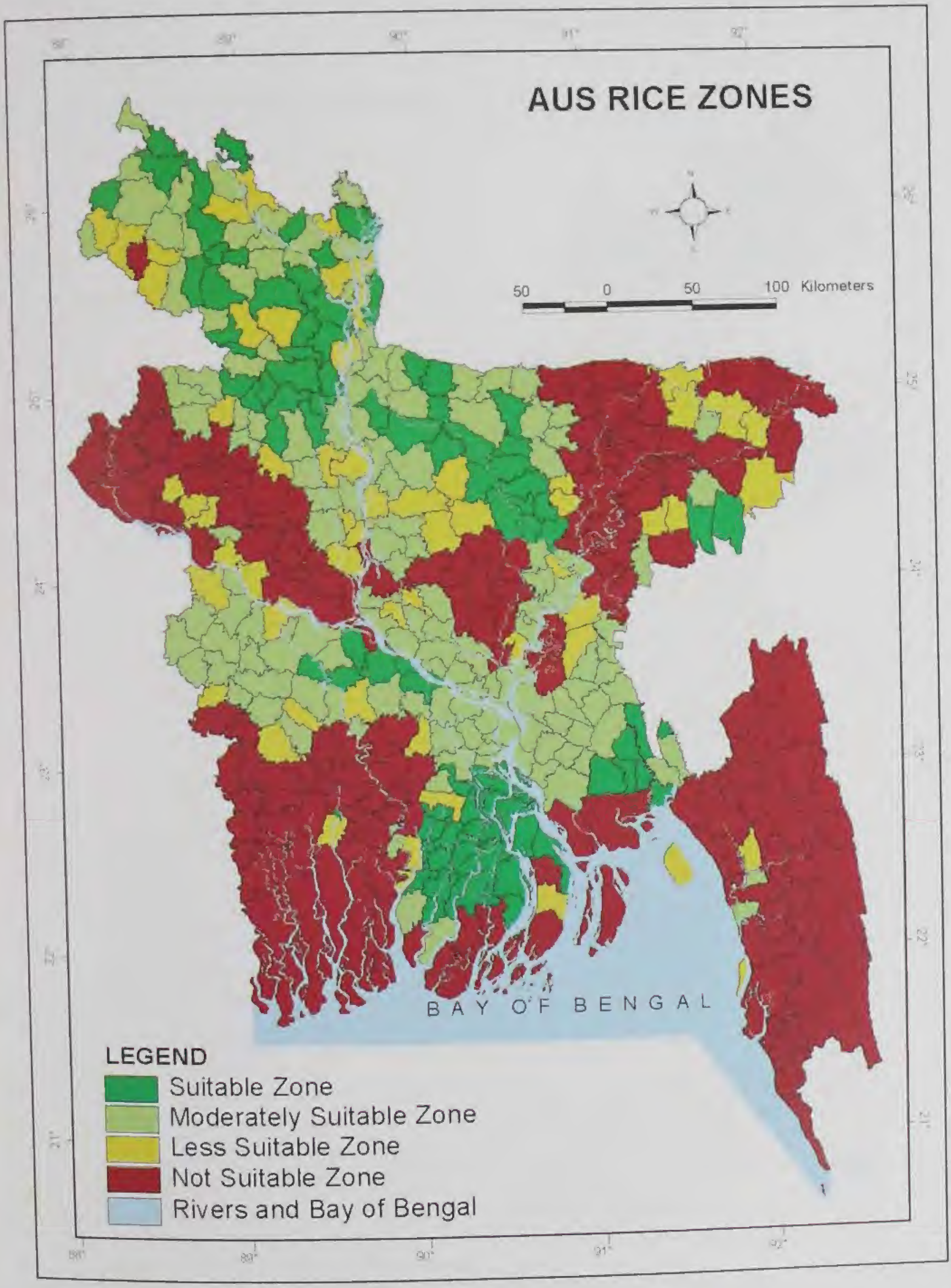

Figure 39. Zones for T. Aus Rice Production

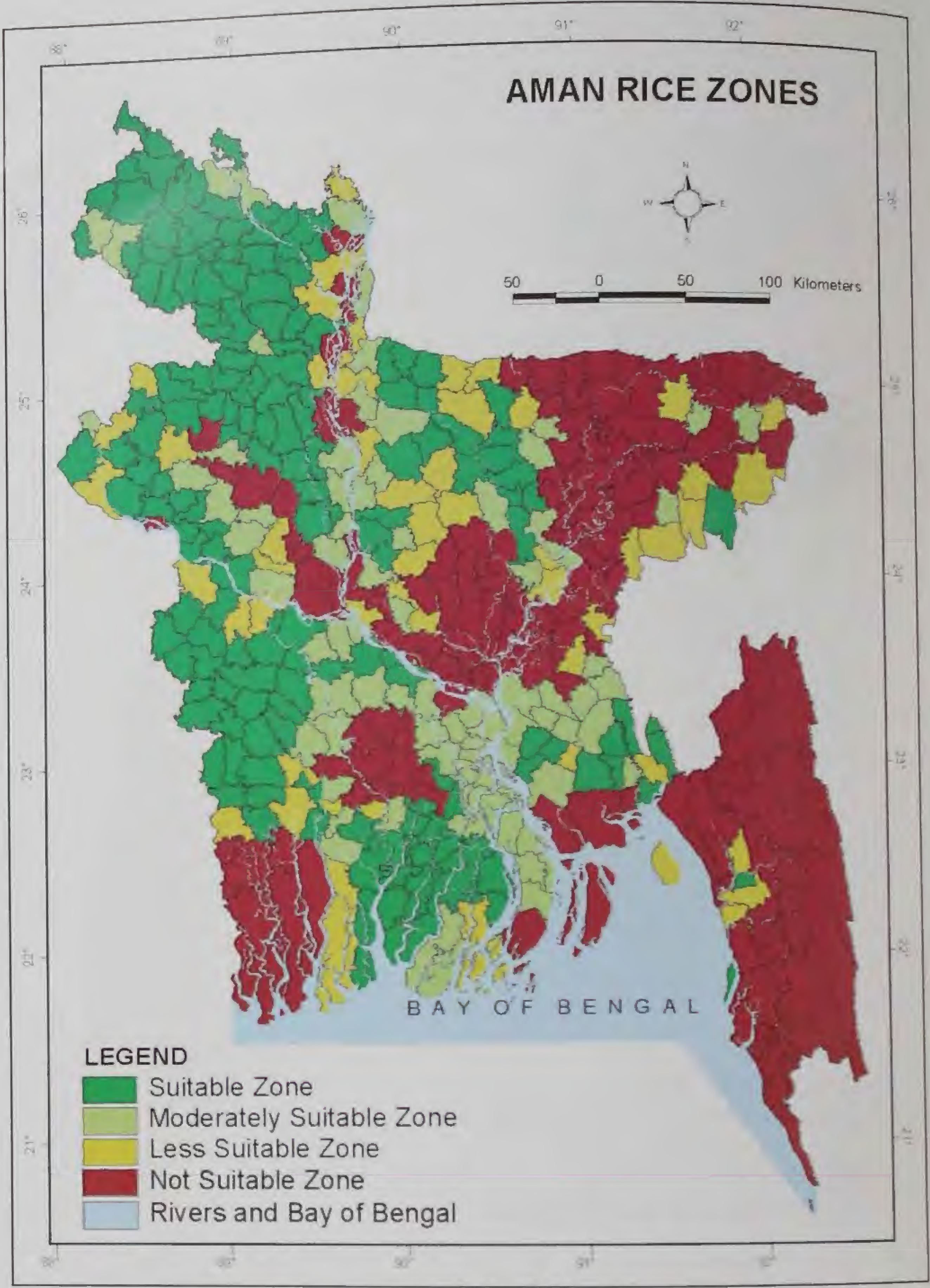

Figure 40. Zones for T. Aman Rice Production

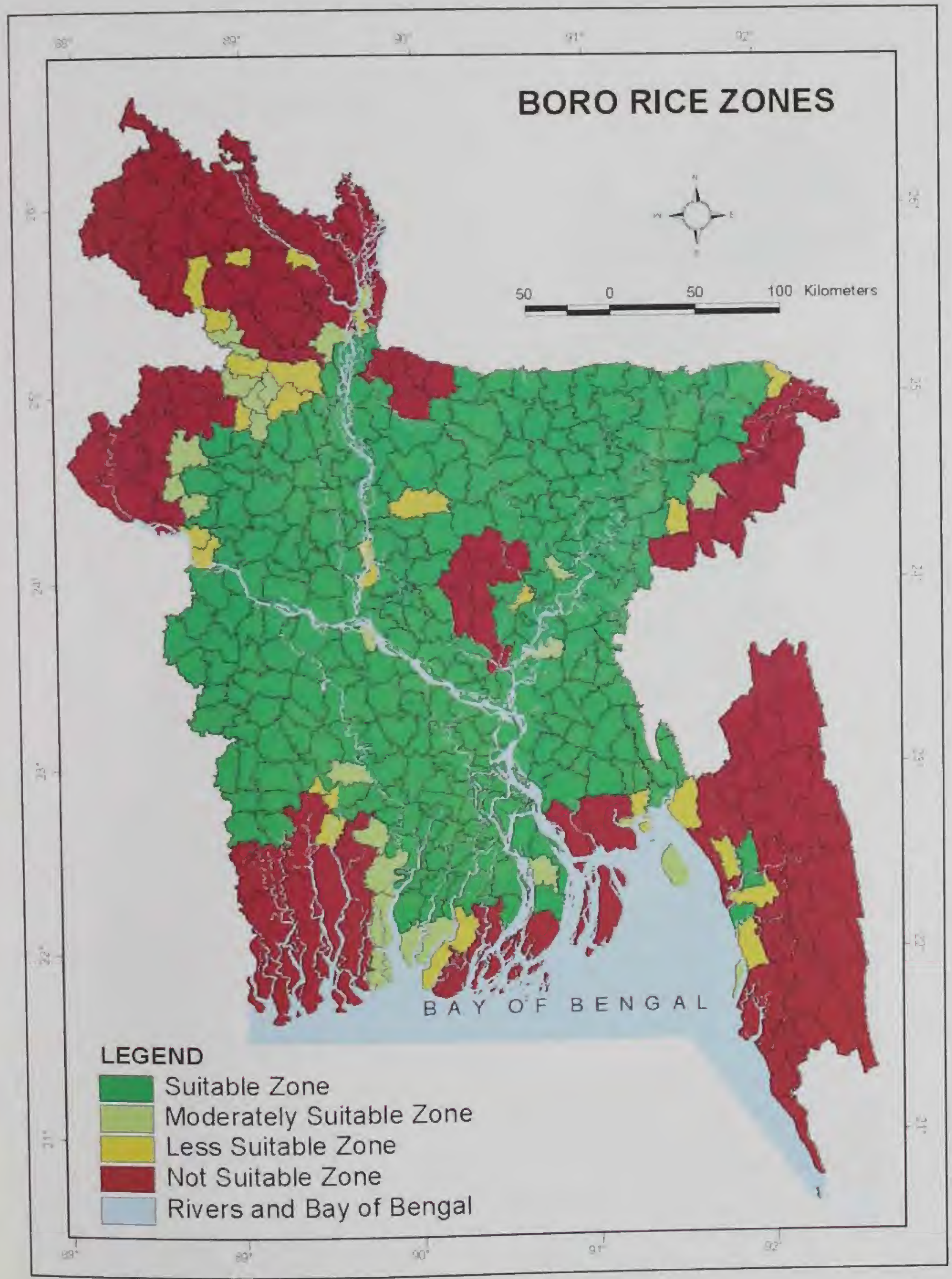

Figure 41. Zones for Boro Rice Production

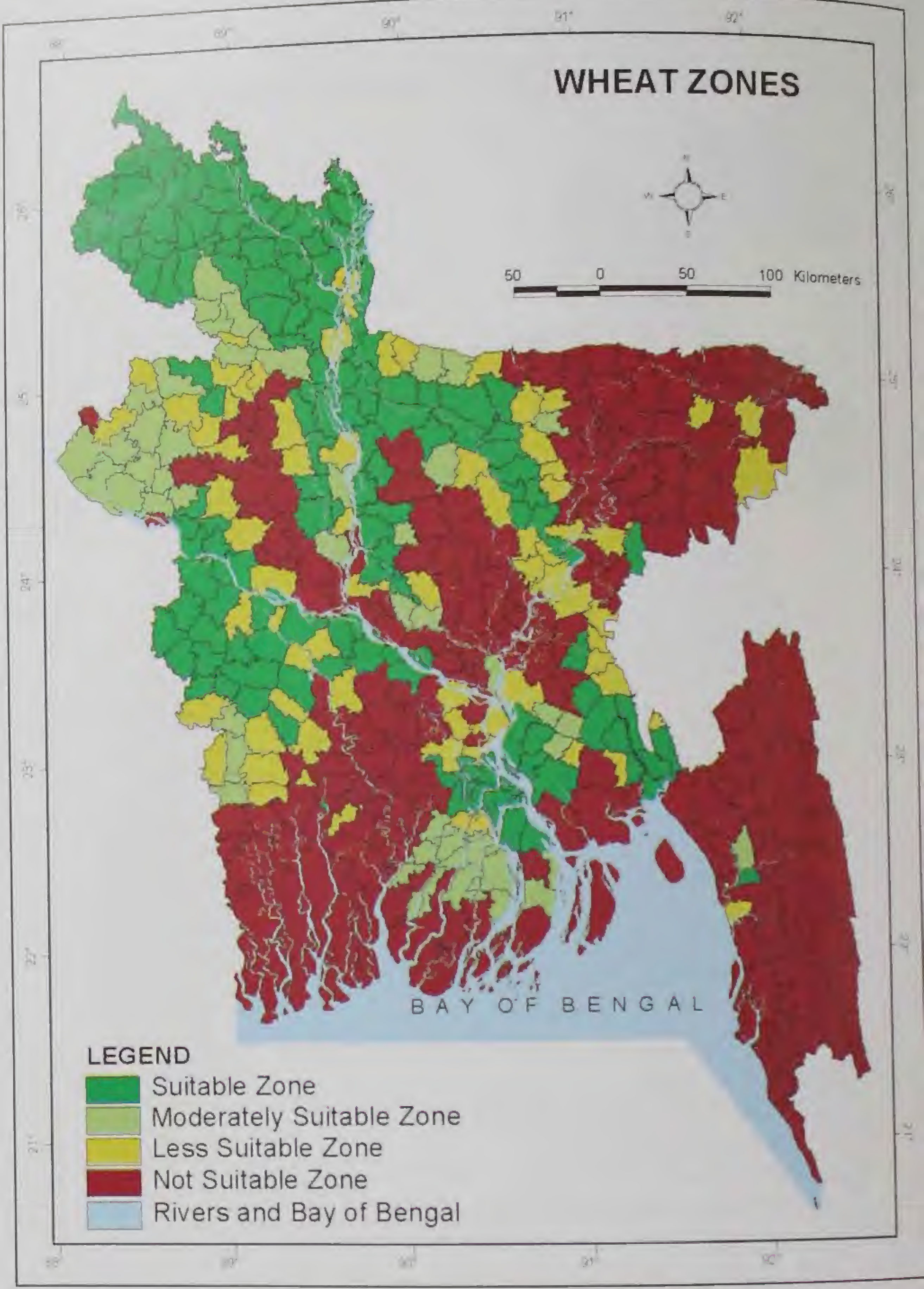

Figure 42. Zones for Wheat Production

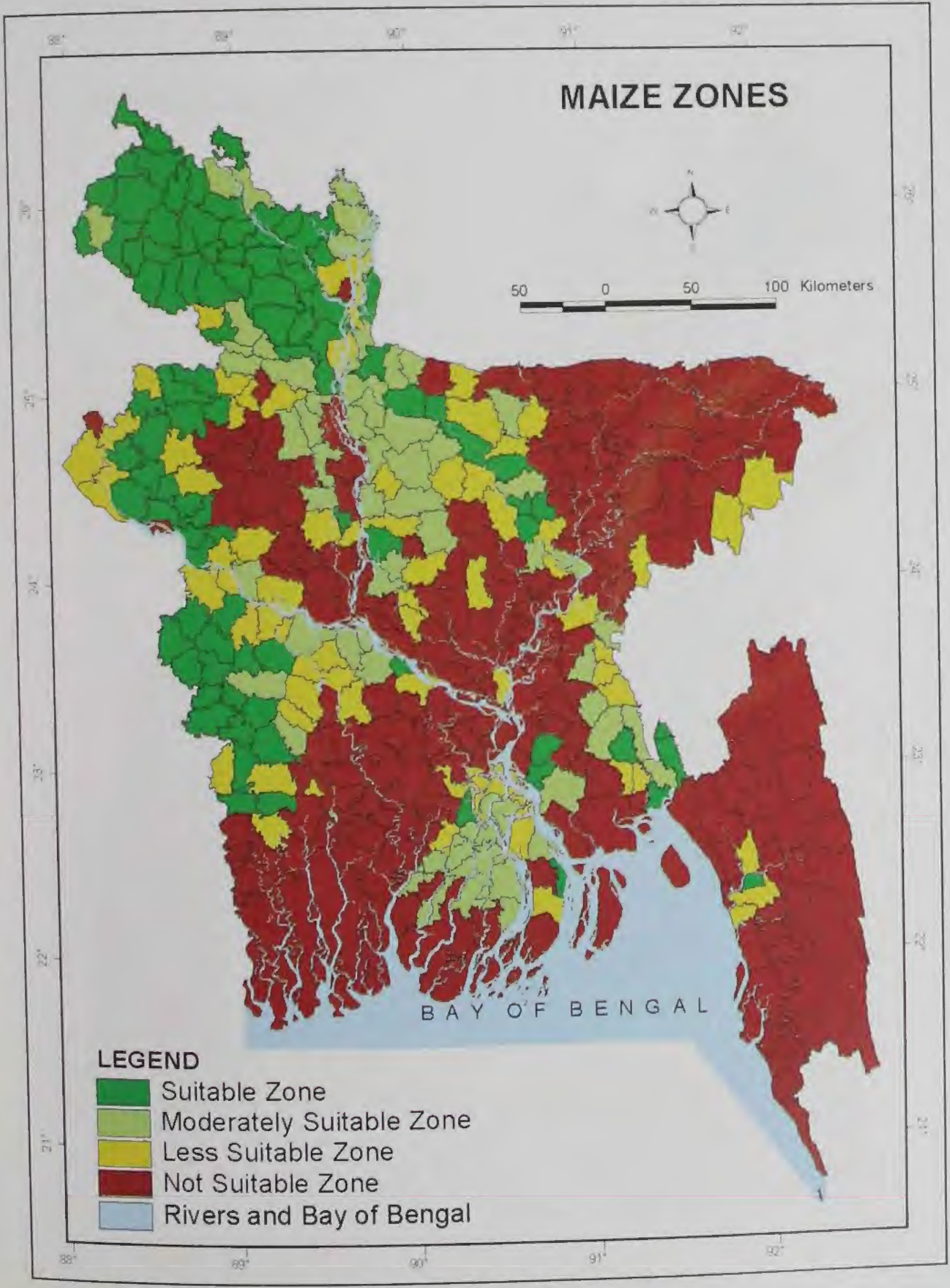

Figure 43. Zones for Maize Production

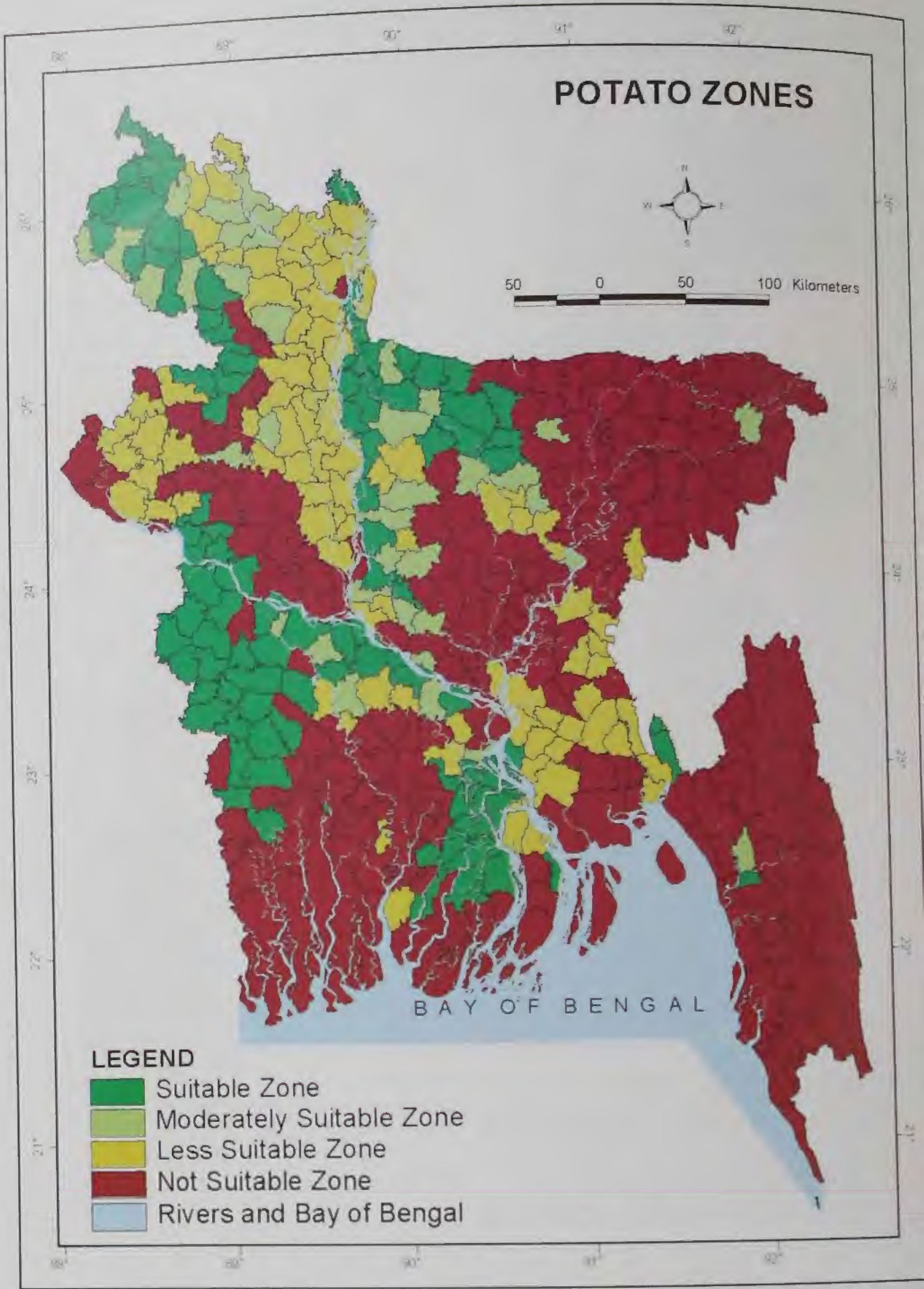

Figure 44. Zones for Potato Production

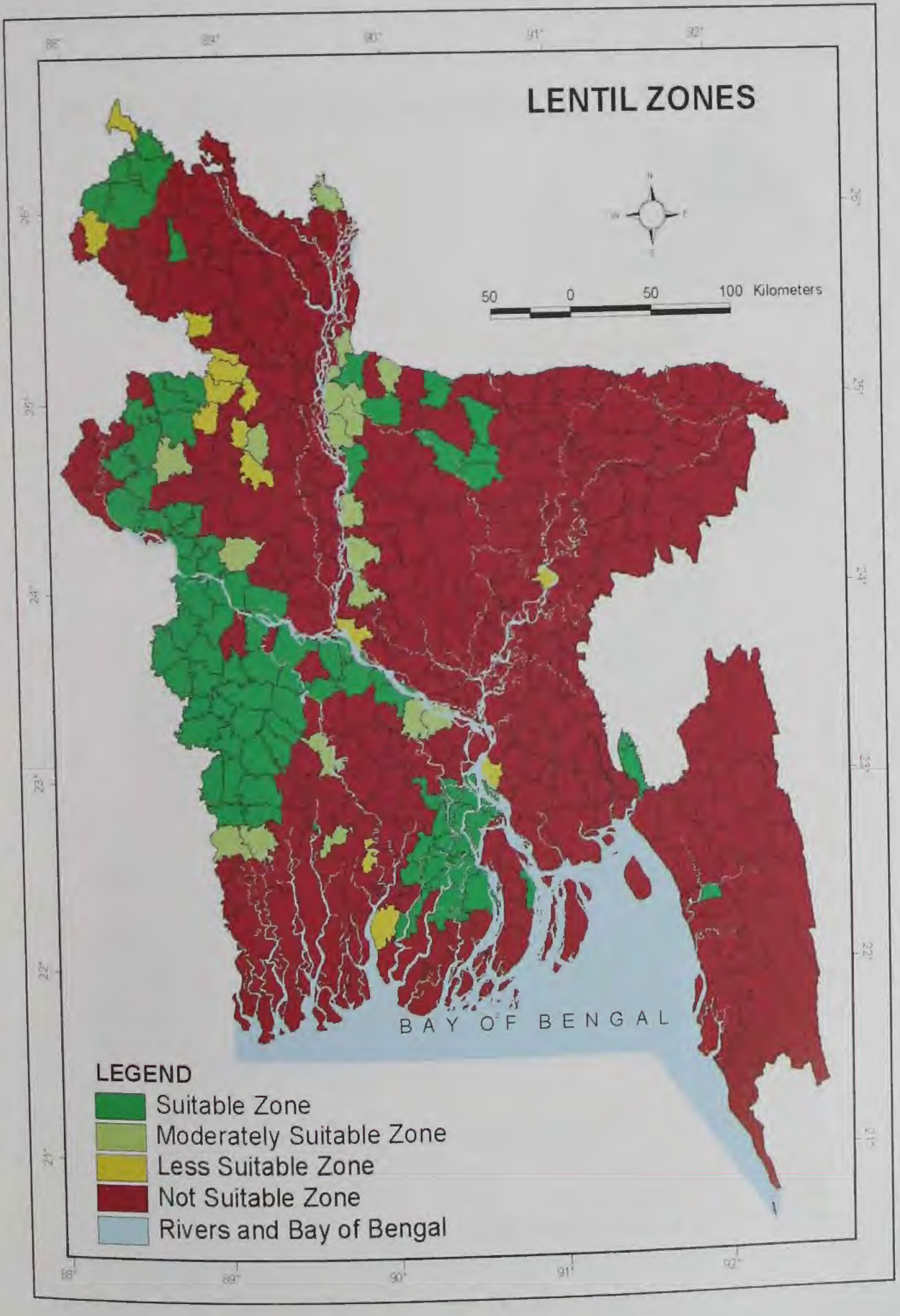

Figure 45. Zones for Lentil Production

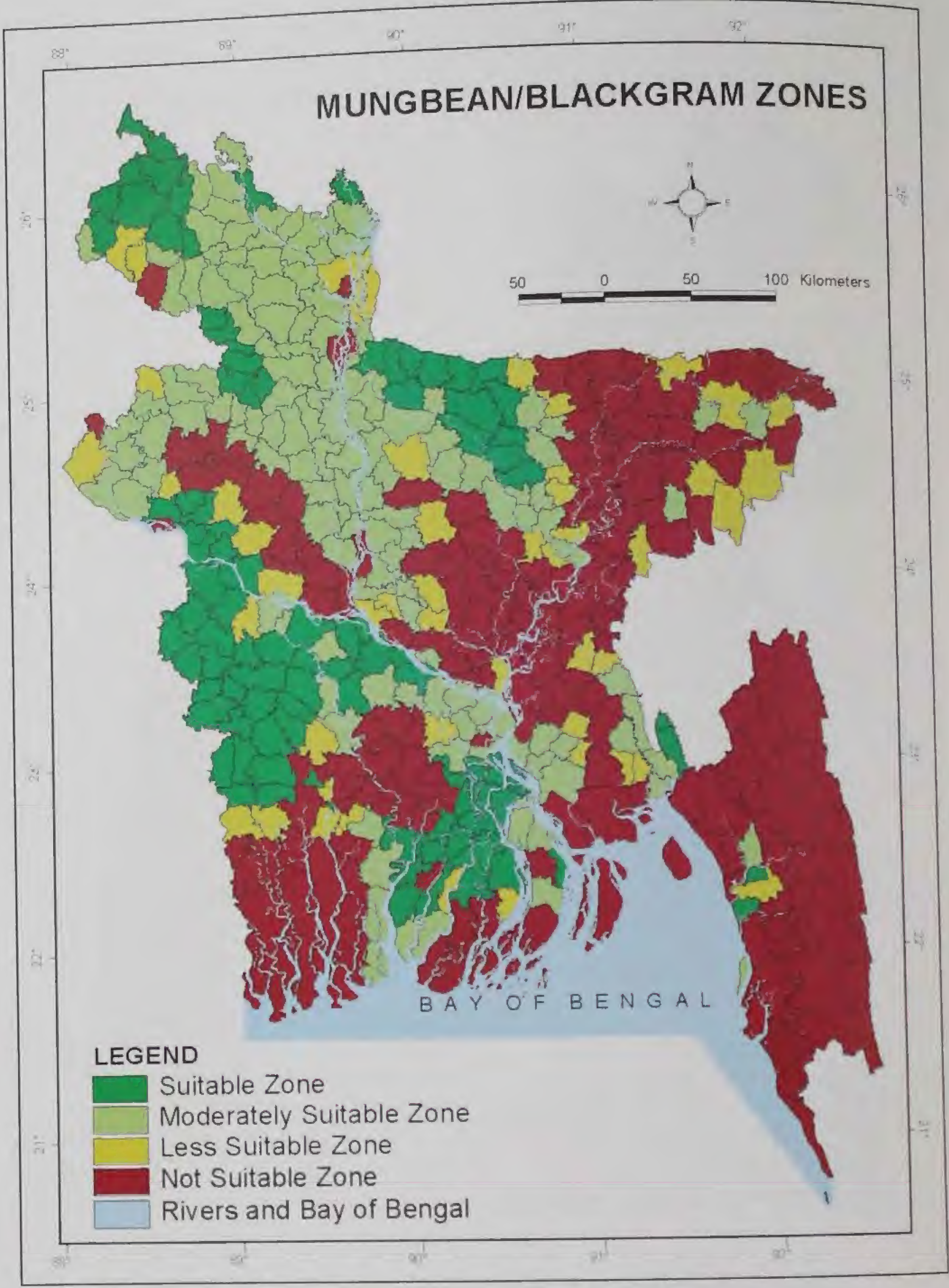

Figure 46. Zones for Mungbean/Blackgram Production

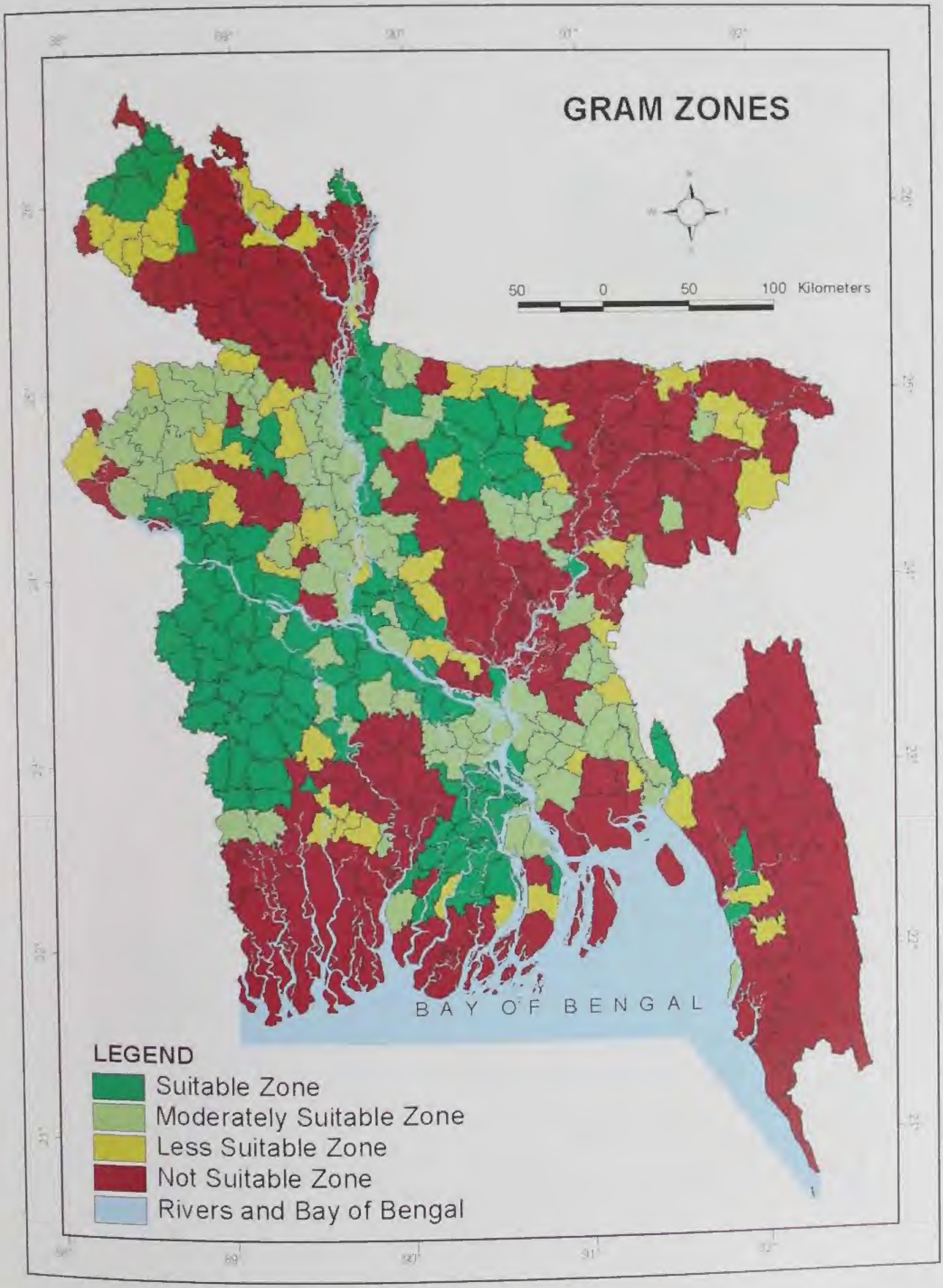

Figure 47. Zones for Gram Production

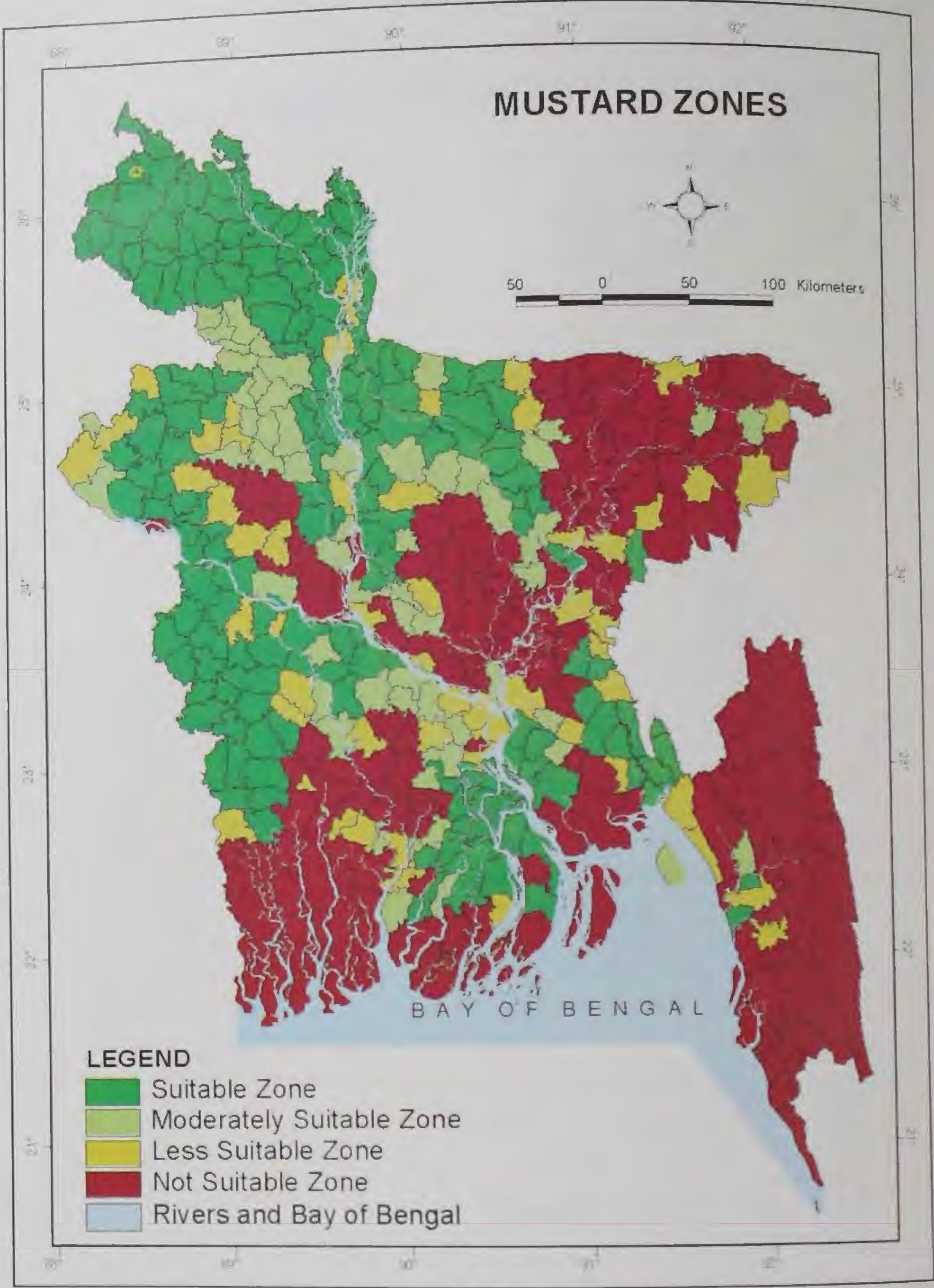

Figure 48. Zones for Mustard Production

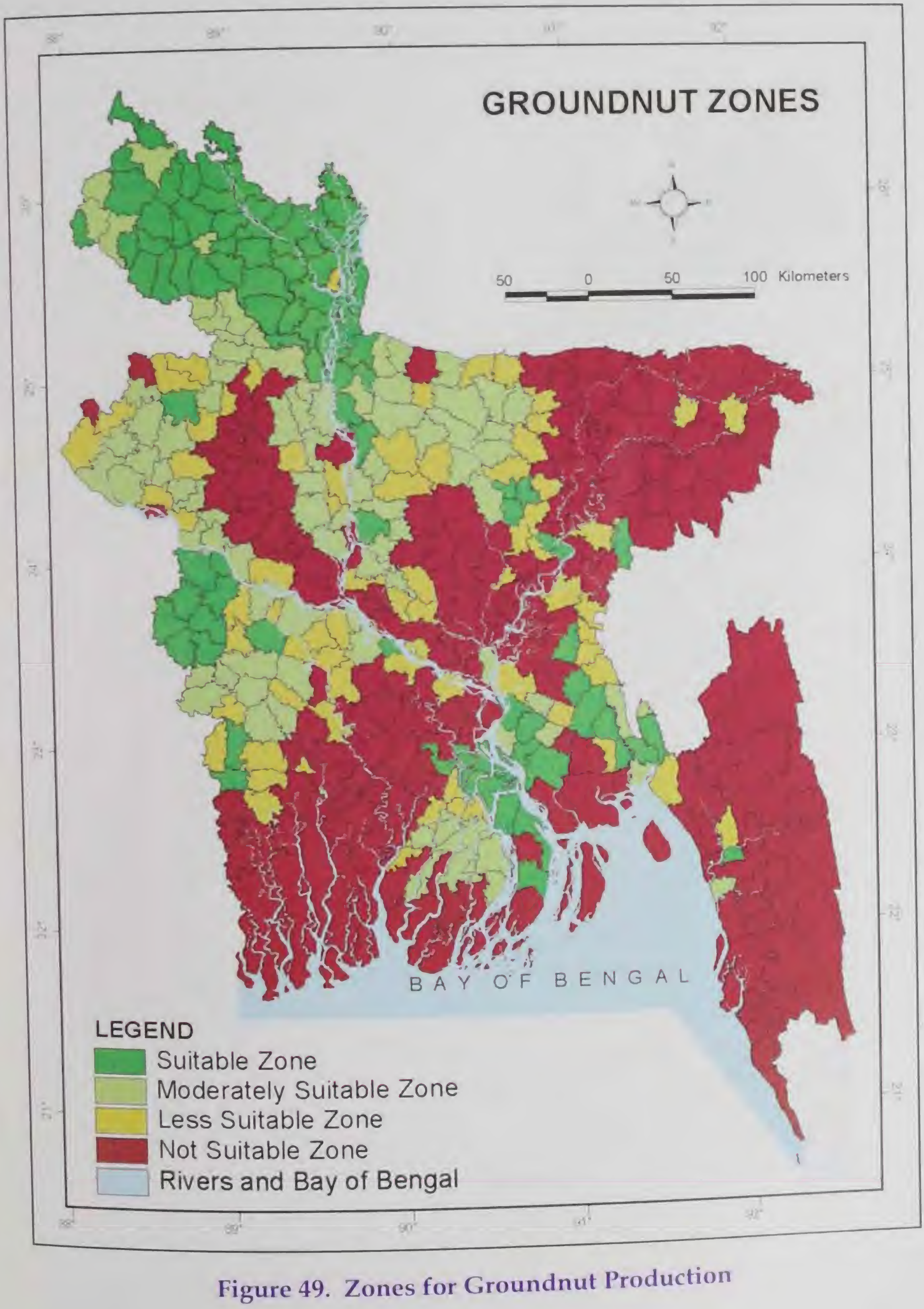

Figure 49. Zones for Groundnut Production

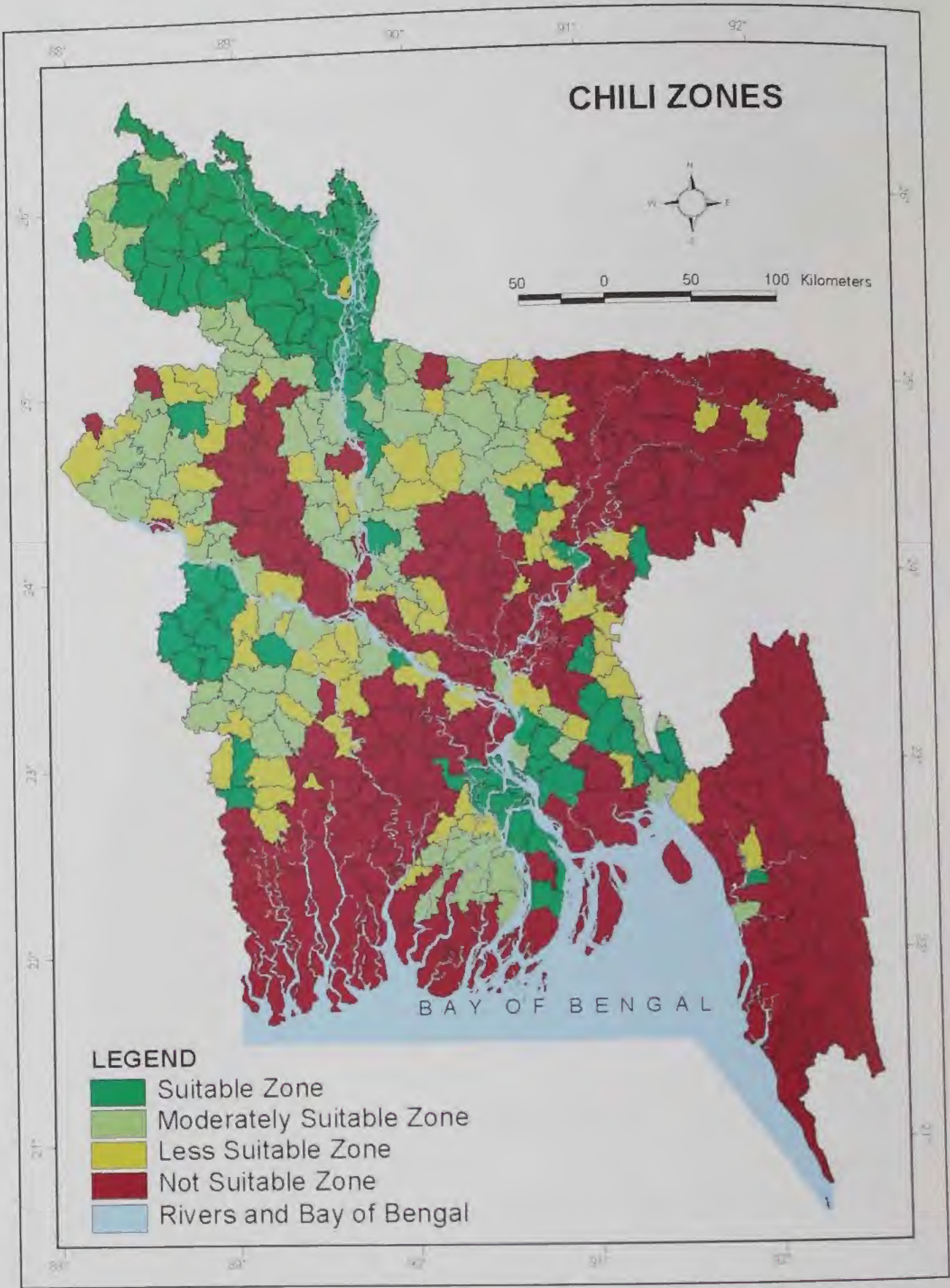

Figure 50. Zones for Chili Production

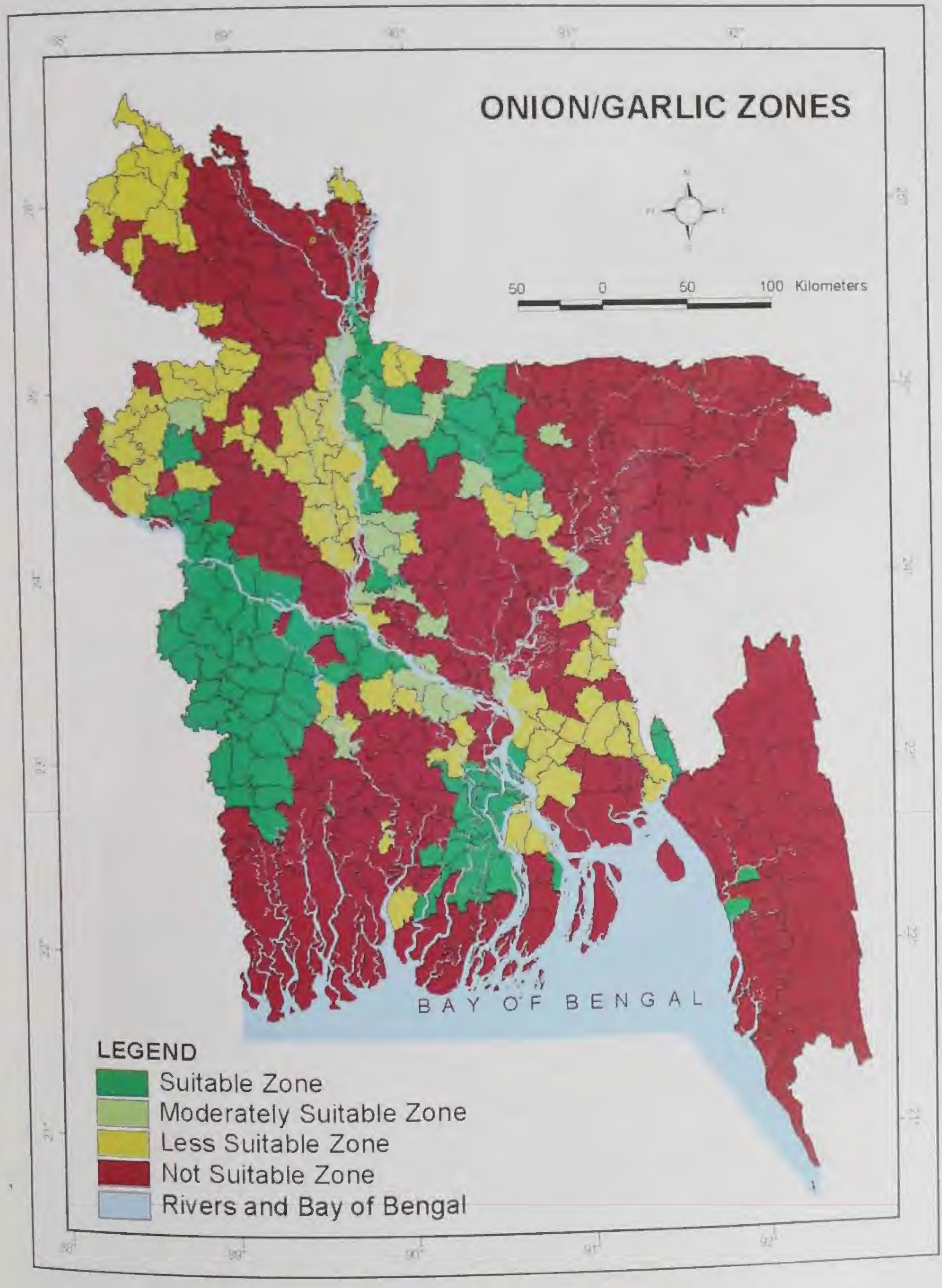

Figure 51. Zones for Onion/Garlic Production

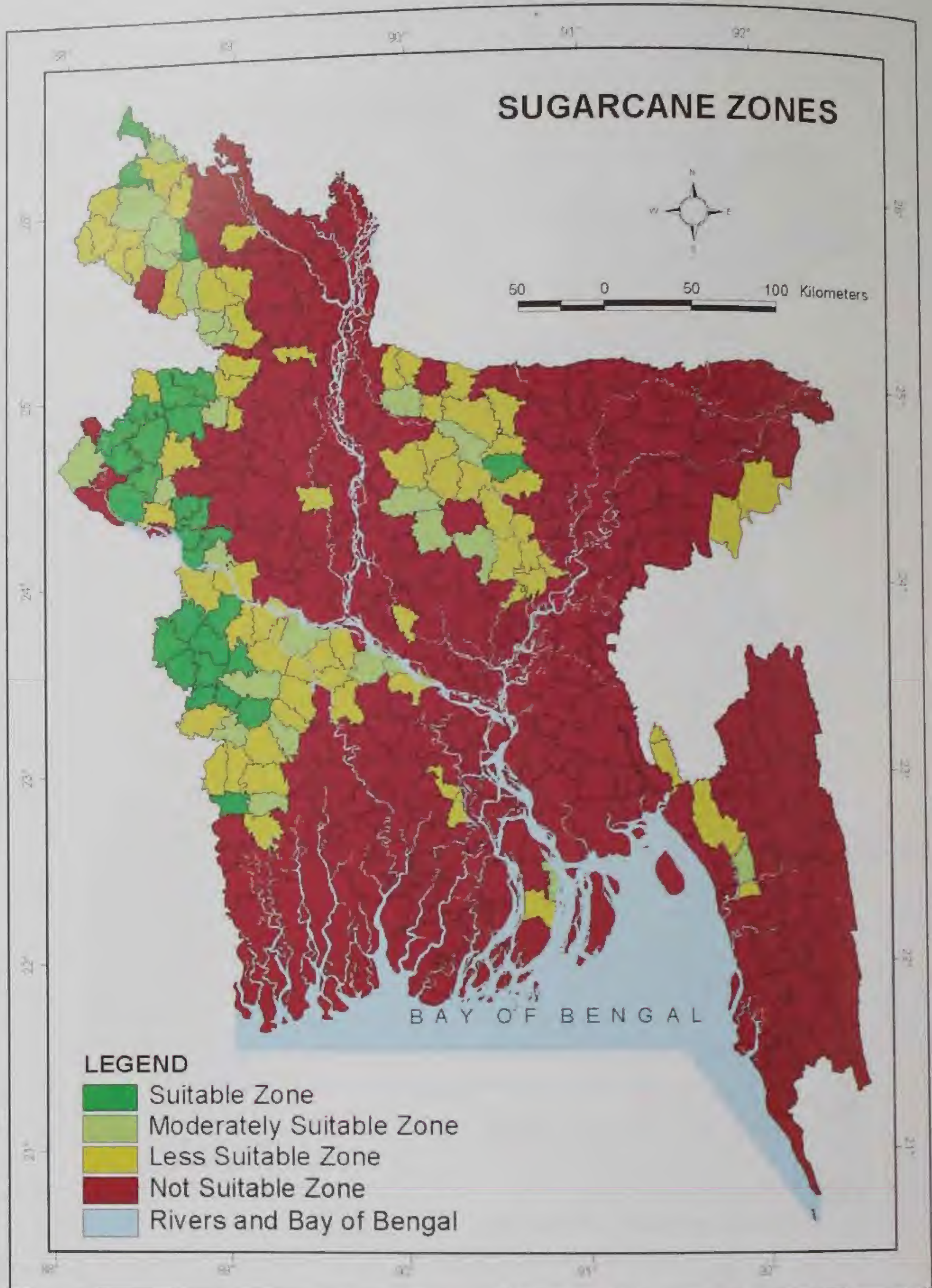

Figure 52. Zones for Sugarcane Production

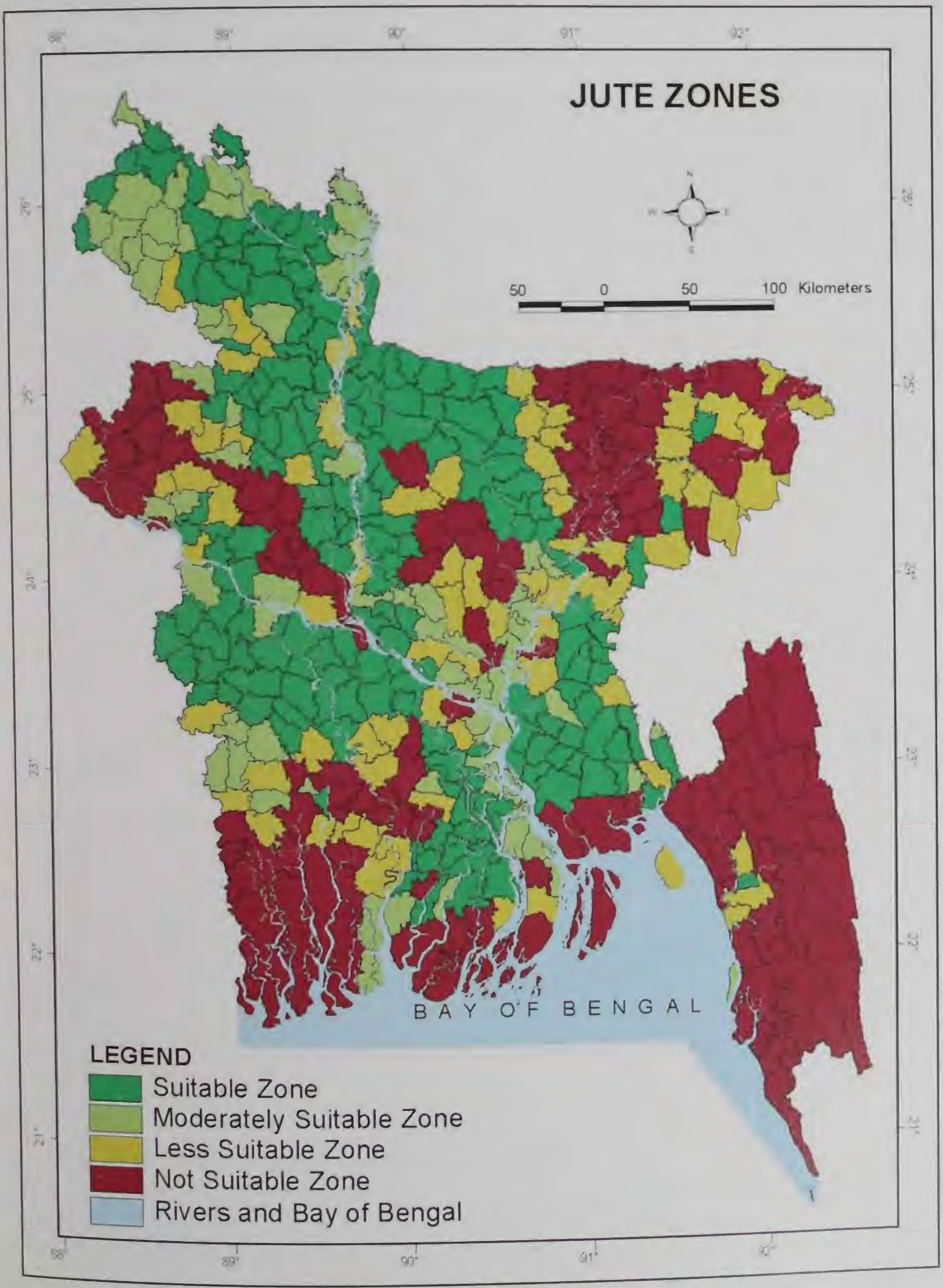

Figure 53. Zones for Jute Production

5. Discourse

5.1. The Economic Importance of Rice

Because of high domestic consumption of rice in Bangladesh, its economic importance differs from that of traditional rice exporting countries. Worldwide, only 5-6% of rice is exported. Bangladesh for example, consumed their entire domestic production and imported around 0.087 million tonnes rice during 2009-10. Besides, as both rice growers and rice eaters for sustenance are poor, there is a constant pressure from rice farmers to keep prices as high as possible, and from consumers as low as possible. This trend is in constant force in all rice-growing countries, but is particularly dominant in the poorest countries. Although, Bangladesh is the fourth largest rice producer in the world, its attachment with, rice is more than in any other countries in the world. About 77% of Bangladesh's agricultural land grow rice, about 70% of population engage themselves in rice production and nearly 50% of all employments are generate in rice sector.

5.2. The Cultural Importance of Rice

Beyond providing sustenance, rice plays an important cultural role in many countries. Products of the rice plant are used for a number of different purposes, such as fuel, thatching, industrial starch, animal feed and artwork. Growing, selling and eating rice is integral to the culture of many countries. Rice is an important part of Bangladeshi culture. Nobanno (new rice harvest) is one of the joyous folk festivals, which is strongly observed in rural Bangladesh.

Nobanno is observed with a lot of fanfare after the new crop comes to home in Agrahayan (Bangla month). Farmers observe this day with platters, rice flour cakes, sweets and muri or khoi (puffed rice or popped rice) made from newly harvested rice.

Rice and fish are the base of the diet. A day without rice is nearly unthinkable. A favorite breakfast dish is panthabhat, leftover cold rice in water or milk mixed with gur (date palm sugar). About 75% of the total calorie and 55% of total protein intake of an average Bangladeshi are obtained from rice.

5.3. Preference and Choice of Crops

Bio-physical suitability of a crop is not the only criterion for selection but food security sometimes forces the farmer in decision making. Choice of crops is also influenced by price, infrastructural and marketing facilities, etc. Example: in Munshiganj potato has become a major crop as because the farmers are rich enough to apply high inputs, produce more and store potatoes in the local cold storage facilities. But agroecologically,

Munshiganj do not have much area which are very suitable for potato. Farmers are not encouraged to grow crops other than rice if they do not get good price for their crops or do not have a market for their produces. Even though production of rice is not lucrative but farmers are growing it for their household food security.

5.4. Technological Interventions

With the development of technologies for adaptation of various crops to adverse conditions like flood, drought, salinity, the suitability of crops may also change. Technologies like introgression of flood and salt tolerant genes into rice has made it somewhat tolerant to flood and salinity and now these can be grown in flash flood prone areas. Likewise, in the saline coastal areas rice can also be grown. On the other hand, some areas may become free from flooding in case polders are built around some low lying areas, where crops can be grown throughout the year. Varietal development of crops, sometimes management and agronomic manipulation can offset the impact of hazards like high/low temperatures, floods, salinity, etc. Areas which are very suitable or suitable now can become unsuitable due to change in biotic or abiotic factors like change in climatic parameters rainfall distribution and temperature regime, emergence of new pests and diseases.

6. Disclaimer

The land resources data used for land suitability assessment and crop zoning is based on reconnaissance soil survey which was undertaken during 1965-73. In recent years, most of the data on land and soil are more than 40 years old. Some of the soil characteristics might have changed. The soil salinity regime has changed substantially. In the last 40 years, many new areas have been affected by different degrees of increased salinity. Due to building of polders in the coastal areas, virtual change has taken place. A agro-climatic conditions have been changing over the last decades due to global warming. More than 26% areas have been affected by salinity compared to the areas in 1970. Soil salinity data collected by SRDI in 2009 has been used in assessing the land suitability and crop zoning.

7. Validation

The maps generated as outputs of a model may show some deviations from reality as there occurred some changes after collection of data. The other things that might have bearing on the outputs are the classification scheme of different land/soil parameters. In some cases these were too much generalized and difficult to tune them at finer level. Therefore, it is suggested that the present crop zoning maps may be tested at field level for its validation.

8. Conclusions

In Bangladesh, population increase coupled with consumption increase resulted from rising incomes enhanced the demand for food. In one hand, arable land is decreasing at an alarming rate. On the other hand, with increased food production, the use of water is increasing. The precious commodity will bring competition among the multiple users, resulting in conflicts. The looming scarcity of fresh water resources for irrigated agriculture leaves little choice to think otherwise but to devise means of growing crops with less water.

GIS provides powerful tools for agricultural planning and modelling. These tools include data automation and processing, conversion, analysis, and visualisation. The use of GIS ensures that data and applications are archived in a common format that can be shared and understood by others. The land resources inventory (LRI) application developed during 1997-2001 allows for the classification and mapping of soil characteristics from the LRI database. The exercise done to delineate the crop suitability and zoning of crop production revealed that the area under different suitability classes differed with crops, cultivars and seasons. During the kharif season, especially during the monsoon, flooding or water logging becomes the most limiting factor. On the other hand, during rabi water scarcity limits cultivation. The suitability maps generated as output of this study delineates areas for potential suitability for particular crops. This may not match with the real practice of farmers. In reality, suitability for growing a crop is not only determined by bio-physical potentiality but also by socioeconomic suitability and may be many other factors like marketing, pricing etc. It also depends on the policy of the government. Therefore, efforts will be made in future to incorporate socioeconomic parameters as well as motivation of farmers. Extension service needs to be strengthened to materialize the crop zoning. Adequate policy support and mechanisms may be devised by the government to execute/implement crop zoning for growing crops in suitable areas. Market linkage, agro-processing, storage facility needs to be developed so that farmers get encouragement to grow crops in suitable areas.

In the present report, crop zoning suitability map was prepared for 15 (fifteen) selected crops based on the availability of the climate related data. Though there were the intentions to include more crops, but could not be incorporated due to unavailability of appropriate climate related information. However, as soon as the relevant data are available in future, the whole report may need to be revised and updated along with the incorporation of more new crops.

9. Recommendations/Suggestions

The major task of crop zoning is to classify the agricultural land suitability for growing specific crop on the basis of soil characteristics, weather conditions and present cultivation practices. After collection and analysis of all available data, the present land suitability was assessed and classified for production of different crops. The outputs are shown in maps, figures and tables. The crop zoning provides basic information for growing potential crop and deriving maximum economic benefit. The assessed areas which are moderately suitable or less suitable for growing crops can become suitable if the specific limiting factors like nutrients, pH, moisture, etc. are ameliorated. Following suggestions are made for crop zoning.

1. The crop zoning is prepared for better utilization of land and water resources.
2. The crop zoning provides opportunities to harvest full potential of the crops grown as per recommendation.
3. The crop can be grown in suitable areas with lower production cost. If the same crop is grown in non suitable areas, the cost of cultivation will be higher compared to suitable areas.
4. The government should adopt appropriate policy so as to ensure proper implementation of crop zoning.
5. Appropriate marketing policies/facilities are needed to facilitate the farming communities to cultivate the specified crops in suitable areas.
6. Training/motivational/awareness creation programmes for farming communities are encouraged to cultivate specific crop suitable for that region.
7. National demonstration programmes to demonstrate the results/ impact/ benefits of crop zoning involving the farmers of the selected crop zones coupled with exchange visits and organized field days.
8. Media propagations (electronic and print) are necessary for confidence building and understanding the importance of crop zoning.

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APPENDIX

Appendix-1. Soil, Water and Climatic Requirements for Rice(*Oryza sativa*)

Water Management:		Irrigated/bunded	
Growing Season:		Sowing/planting	Harvesting
Kharif-I	T. Aus (HYV)	Mid-March-Mid-April	Mid-June- Early-August
Kharif-I	T. Aman (HYV)	Late-June-Early September	December- Early-January
Rabi	Boro (HYV)	December- Mid-February	Mid-April-June
Land Factors		**Range**	**Optimum**
Soil Permeability (cm d^{-1})		Slow to moderate	Slow (<12 cm d^{-1})
Effective Soil Depth (m)		0.25 to 1.20 m	> 0.90 m
Available Soil Moisture (mm)+		>400 mm (900-1200 mm)*	>400 mm (>1000 mm)*
Nutrient Status		Low to high	High
Soil Reaction (pH)		4.5-8.2	5.5-7.5
Soil Salinity(dS m^{-1} or m mhos cm^{-1})		0 to < 3 dS m^{-1} (10% yield loss)	0 to <2 dS m^{-1}
Soil Consistency/Texture		C1-C4 / SiCL, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiCL, CL, Si, SiL, SC
Drainage		Imperfectly to moderately- well drained	Poor to Imperfectly drained
Depth of inundation (cm)		Saturated to flooded up to 25% of plant height	Saturated to flooded up to 10-20 cm
Slope (%)		0 to <3	Flat floodplains
Climatic Factors		**Range**	**Optimum**
Temperature		10 - 38 °C	30-32 °C
Rainfall		1200-1600 mm $year^{-1}$	1000-1200 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-2. Soil, Water and Climatic Requirements for Wheat *(Triticum aestivum)*

Water Management:	Irrigated	
Growing Season:	Sowing/planting	Harvesting
Rabi	November-December	March-Mid
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.90 to 2.00 m	> 0.90 to 1.50 m
Available Soil Moisture (mm) +	200 to 350 mm (350-500 mm)*	300 to <400 mm (350 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.2-8.5	6.0-8.2
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 7.4 dS m^{-1} (10% yield loss)	< 6.0 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, SC, L
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	3-32°C	15-25° °C
Precipitation	350-1200 mm $year^{-1}$	400-1100 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-3. Soil, Water and Climatic Requirements for Maize *(Zea mays)*

Water Management:	Irrigated	
Growing Season:	**Sowing/planting**	**Harvesting**
Rabi	October-November	Mid-February-March
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.90 to 2.00 m	> 0.90 to 1.50 m
Available Soil Moisture (mm) +	200 to 350 mm (350-500 mm)*	300 to <400 mm (350 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	4.0-9.0	6.0-7.0
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 7.4 dS m^{-1} (10% yield loss)	< 6.0 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, SC, L
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	10-46 °C	18-32°C
Precipitation	1000-1500 mm $year^{-1}$	500-1200 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-4. Soil, Water and Climatic Requirements for Potato(*Solanum tuberosum*)

Water Management:	Irrigated	
Growing Season:	Sowing/planting	Harvesting
Rabi	Mid-September – Mid-November	Mid-January-March
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.50 to 1.00 m	> 0.60 to 1.00 m
Available Soil Moisture (mm) +	>150 to 400 mm (500-700 mm)*	300 to <400 mm (700 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.0-5.5	5.6-7.3
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 4.0 dS m^{-1} (10% yield loss)	< 2.0 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiL, SC, L, SCL, SL	C1-C2/ L, SCL,
Drainage	Well drained to imperfectly drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	14-28 °C	18-21 °C
Precipitation	400-1200 mm $year^{-1}$	300-700 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

+ In case of irrigated crops water is applied as and when required

Appendix-5. Soil, Water and Climatic Requirements for Lentil(*Lens esculanta*) and Gram/Chickpea (*Cicer arietinum*)

Water Management:	Rain-fed	
Growing Season:	**Sowing/planting**	**Harvesting**
Rabi	Mid-October - Mid-November	Late-January - Early-March
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.60 to 1.5 m	1.00 to 1.50 m
Available Soil Moisture (mm) +	>150 to 400 mm (250-500 mm)*	300 to <400 mm (300-350 mm)*
Nutrient Status	Low to high	Medium
Soil Reaction (pH)	5.5 - 6.5 (Lentil) 5.0-8.2 (Chickpea)	6.0-7.5
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 2.0 dS m^{-1} (10% yield loss)	0.0 - < 0.5 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, L, SC, SCL
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	20 - 25 °C	20 - 25 °C
Precipitation	700 mm $year^{-1}$	300 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

+ In case of irrigated crops water is applied as and when required

Appendix-6. Soil, Water and Climatic Requirements forMungbean (*Vigna radiata*) and Blackgram (*Vigna phaseolus*)

Water Management:	Rain-fed	
Growing Season:	Sowing/planting	Harvesting
Kharif-I Kharif-II	March - Mid-April	Late-January - Early-March
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.60 to 1.5 m	1.00 to 1.50 m
Available Soil Moisture (mm) +	>150 to 400 mm (250-500 mm)*	300 to <400 mm (300-350 mm)*
Nutrient Status	Low to high	Medium
Soil Reaction (pH)	5.5 - 6.5 (Lentil) 5.0-8.2 (Chickpea)	6.0-7.5
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 2.0 dS m^{-1} (10% yield loss)	0.0 - < 0.5 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, L, SC, SCL
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	25 - 45 °C	25-35 °C
Precipitation	700-900 mm $year^{-1}$	300 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-7. Soil, Water and Climatic Requirements for Mustard(*Brassica campestris/ Brassica juncea*)

Water Management:	Irrigated/Rainfed	
Growing Season:	**Sowing/planting**	**Harvesting**
Rabi (*B. Campestris*, 65-90 days) (*B. juncea*, 200-120 days)	November - Early December	Late January - Early March
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.60 to 1.5 m	1.00 to 1.50 m
Available Soil Moisture (mm) +	>150 to 400 mm (250-500 mm)*	300 to <400 mm (300-350 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.5-8.2	6.2-7.5
Soil Salinity (dS m^{-1}or m mhos cm^{-1})	0 to < 2.8 dS m^{-1} (10% yield loss)	0.0 - < 1.8 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ L, SC, SCL
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	20 - 25 °C	20 - 24 °C
Precipitation	700 mm $year^{-1}$	350 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix- 8. Soil, Water and Climatic Requirements for Groundnut (*Arachis hypogaea*)

Water Management:	**Irrigated/Rainfed**	
Growing Season:	**Sowing/planting**	**Harvesting**
Rabi	End September– Early November	Late February - Mid April
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.60 to 1.5 m	1.00 to 1.50 m
Available Soil Moisture (mm) +	>150 to 400 mm (250-500 mm)*	300 to <400 mm (300-350 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.4-8.2	6.0-7.5
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 3.2 dS m^{-1} (10% yield loss)	0.0 - < 1.8 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ L, SL, SCL
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	20 - 25 °C	20 - 24 °C
Precipitation	700-900 mm $year^{-1}$	350 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-9. Soil, Water and Climatic Requirements for Chili *(Capsicum annuum)*

Water Management:	Irrigated/Rainfed	
Growing Season:	**Sowing/planting**	**Harvesting**
Kharif	May - June	September - December
Rabi	December - January	March - May
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	> 0.90 to 2.00 m	> 0.90 to 1.50 m
Available Soil Moisture (mm) +	200 to 350 mm (350-500 mm)*	300 to <400 mm (350 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.2-8.5	6.0-8.2
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 7.4 dS m^{-1} (10% yield loss)	< 6.0 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, SC, L
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	14-28 °C	18-26 °C
Precipitation	400-1200 mm $year^{-1}$	350 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

+ In case of irrigated crops water is applied as and when required

Appendix-10. Soil, Water and Climatic Requirements for Onion (*Allium cepa*) and Garlic (*Allium sativum*)

Water Management:	Irrigated/Rain-fed	
Growing Season	Sowing/planting	Harvesting
Rabi	October -November	February - April
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	0.25 to 1.20 m	> 0.90 m
Available Soil Moisture (mm)+	>400 mm (900-1200 mm)*	>400 mm (>1000 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.5-8.2	6.2-6.8
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 3 dS m^{-1} (10% yield loss)	0 to <1.2 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, SC, L
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand flooding	Not flooded, cannot withstand flooding
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	16-22 °C	16-22 °C
Precipitation	900-1400 mm $year^{-1}$	350 - 600 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-11. Soil, Water and Climatic Requirements for Sugarcane (*Saccharum officinarum*)

Water Management:	Irrigated/Rain-fed	
Growing Season:	Sowing/planting	Harvesting
Annual/Perennial	October -November	October-March
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Moderate to rapid (>12 to >305 cm d^{-1})	Rapid
Effective Soil Depth (m)	1.00 to 3.00 m	1.50 to 2.00 m
Available Soil Moisture (mm) +	>300 to 400 mm (1300-2000 mm)*	300 to <400 mm (1500-2000 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	4.5-8.5	5.5-7.5
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 3.3 dS m^{-1} (10% yield loss)	< 1.7 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, SiL, CL, Si, SiCL, SC, L, SCL,	C1-C2/ SiC, SiL, CL, Si, SiCL
Drainage	Well drained to moderately well drained	Well drained
Depth of inundation (cm)	Not flooded, cannot withstand partial flooding up to 1-2 weeks	Not flooded
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	15-45 °C	24-32 °C
Precipitation	1100-1500 mm $year^{-1}$	1300 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix-12. Soil, Water and Climatic Requirements for Jute (*Corchorus oliterius / Chorcorus capsularis*)

Water Management:	**Irrigated/Rainfed**	
Growing Season:	**Sowing/planting**	**Harvesting**
Kharif-I	End of March-Mid April	October-November
Land Factors	**Range**	**Optimum**
Soil Permeability (cm d^{-1})	Slow to moderate (<12 to 305 cm d^{-1})	Moderate
Effective Soil Depth (m)	> 0.50 to 1.20 m	> 1.20 m
Available Soil Moisture (mm) +	>300 to 400 mm (500-700 mm)*	300 to <400 mm (300-350 mm)*
Nutrient Status	Low to high	High
Soil Reaction (pH)	5.2-8.5	6.0-8.2
Soil Salinity (dS m^{-1} or m mhos cm^{-1})	0 to < 7.4 dS m^{-1} (10% yield loss)	< 6.0 dS m^{-1}
Soil Consistency/Texture	C1-C2 / SiC, CL, Si, SiL, SC, L, SCL, SL	C1-C2/ SiL, SC, L
Drainage	Well drained to moderately well drained	Well drained to moderately well drained
Depth of inundation (cm)	Not flooded, cannot withstand partial flooding up to 1-2 weeks	Not flooded
Slope (%)	0 to <3	Flat floodplains
Climatic Factors	**Range**	**Optimum**
Temperature	16-35 °C	18-33 °C
Precipitation	1100-1500 mm $year^{-1}$	750 mm

C1 = not more than slightly firm, slightly sticky, slightly plastic, hard

C2 = fine, very firm, sticky, plastic, hard, very hard

C3 = extremely firm, very sticky, very plastic, extremely hard

C4 = organic material to at least 25 cm below the surface

SiCL = silty clay loam, CL= clay loam, Si = silt, SiL =silt loam, SC = sandy clay, L = loam, SCL = sandy clay loam, SL = sandy loam, LfS = loamy fine sand, LS = loamy sand, LcS = loamy coarse sand, fS = fine sand, S = sand, cS = coarse sand

* Maximum evapotranspiration

\+ In case of irrigated crops water is applied as and when required

Appendix 13. Upazilas-wise Different Suitability Zone for Boro Rice Production

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
10419	Barguna	Bamna	1	S	7202
10447	Barguna	Betagi	1	S	11291
10602	Barisal	Agailjhara	1	S	12873
10603	Barisal	Babuganj	1	S	10825
10607	Barisal	Bakerganj	1	S	31631
10610	Barisal	Banaripara	1	S	10117
10632	Barisal	Gaurnadi	1	S	10472
10636	Barisal	Hizla	1	S	19654
10651	Barisal	Barisal	1	S	19221
10662	Barisal	Mehendiganj	1	S	25609
10669	Barisal	Muladi	1	S	18785
10694	Barisal	Ujirpur	1	S	19532
10918	Bhola	Bhola	1	S	23473
10929	Bhola	Daulatkhan	1	S	8402
10954	Bhola	Lalmohan	1	S	21559
10991	Bhola	Tajumuddin	1	S	10185
14240	Jhalakati	Jhalakati	1	S	15737
14243	Jhalakati	Kathalia	1	S	11940
14273	Jhalakati	Nalchiti	1	S	15257
14284	Jhalakati	Rajapur	1	S	12438
17838	Patuakhali	Bauphal	1	S	36073
17852	Patuakhali	Dashmina	1	S	16863
17876	Patuakhali	Mirzaganj	1	S	11999
17895	Patuakhali	Patuakhali	1	S	30210
17914	Pirojpur	Bhandaria	1	S	10415
17947	Pirojpur	Kawkhali	1	S	4816
17958	Pirojpur	Mathbaria	1	S	22887
17976	Pirojpur	Nazirpur	1	S	16670
17980	Pirojpur	Pirojpur	1	S	20299
17987	Pirojpur	Sarupkati	1	S	11555
21202	Brahmanbaria	Akhaura	1	S	8760
21204	Brahmanbaria	Banchharampur	1	S	14565
21213	Brahmanbaria	Brahmanbaria	1	S	43086
21263	Brahmanbaria	Kasba	1	S	17515
21285	Brahmanbaria	Nabinagar	1	S	29109
21290	Brahmanbaria	Nasirnagar	1	S	25821

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
21294	Brahmanbaria	Sarail	1	S	18504
21322	Chandpur	Chandpur	1	S	12501
21345	Chandpur	Faridganj	1	S	15643
21347	Chandpur	Haimchar	1	S	6598
21349	Chandpur	Hajiganj	1	S	13472
21358	Chandpur	Kachua	1	S	17793
21376	Chandpur	Matlab	1	S	26614
21395	Chandpur	Shahrasti	1	S	11817
21504	Chittagong	Anwara	1	S	9461
21512	Chittagong	Boalkhali	1	S	6993
21574	Chittagong	Rauzan	1	S	13884
21909	Comilla	Barura	1	S	18531
21915	Comilla	Brahmanpara	1	S	10507
21918	Comilla	Burichang	1	S	12801
21927	Comilla	Chandina	1	S	15592
21931	Comilla	Chauddagram	1	S	21922
21936	Comilla	Daudkandi	1	S	39642
21940	Comilla	Debiduar	1	S	18763
21967	Comilla	Comilla	1	S	20572
21972	Comilla	Laksham	1	S	33399
21981	Comilla	Muradnagar	1	S	29062
21987	Comilla	Nangalkot	1	S	19270
23014	Feni	Chhagalnaiya	1	S	10594
23025	Feni	Daganbhuiya	1	S	12365
23029	Feni	Feni	1	S	15591
23051	Feni	Parshuram	1	S	16929
23094	Feni	Sonagazi	1	S	16920
25143	Lakshmipur	Laksmipur	1	S	32925
25158	Lakshmipur	Raipur	1	S	10559
25165	Lakshmipur	Ramganj	1	S	12476
27507	Noakhali	Begumganj	1	S	30586
27510	Noakhali	Chatkhil	1	S	8992
27580	Noakhali	Senbag	1	S	12362
32614	Dhaka	Dhamrai	1	S	26383
32618	Dhaka	Dohar	1	S	8868
32638	Dhaka	Keraniganj	1	S	13220
32662	Dhaka	Nawabganj	1	S	19518

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
32903	Faridpur	Alfadanga	1	S	10541
32910	Faridpur	Bhanga	1	S	17152
32918	Faridpur	Boalmari	1	S	22787
32921	Faridpur	Char Bhadrasan	1	S	7959
32947	Faridpur	Faridpur	1	S	31134
32956	Faridpur	Madhukhali	1	S	17784
32962	Faridpur	Nagarkanda	1	S	32375
32984	Faridpur	Sadarpur	1	S	21289
33334	Gazipur	Kaliganj	1	S	18738
33532	Gopalganj	Gopalganj	1	S	32564
33543	Gopalganj	Kasiani	1	S	22945
33551	Gopalganj	Kotalipara	1	S	32462
33558	Gopalganj	Muksudpur	1	S	24352
33591	Gopalganj	Tungipara	1	S	10843
33915	Jamalpur	Dewanganj	1	S	22707
33929	Jamalpur	Islampur	1	S	26486
33936	Jamalpur	Jamalpur	1	S	42274
33958	Jamalpur	Madarganj	1	S	22177
33961	Jamalpur	Melandaha	1	S	20548
33985	Jamalpur	Sarishabari	1	S	21558
34802	Kishoreganj	Ashtagram	1	S	25504
34806	Kishoreganj	Bajitpur	1	S	14649
34811	Kishoreganj	Bhairab	1	S	7308
34827	Kishoreganj	Hossainpur	1	S	9257
34833	Kishoreganj	Itna	1	S	37287
34842	Kishoreganj	Karimganj	1	S	16235
34845	Kishoreganj	Katiadi	1	S	17329
34849	Kishoreganj	Kishoreganj	1	S	12537
34854	Kishoreganj	Kuliarchar	1	S	8068
34859	Kishoreganj	Mithamoin	1	S	19079
34876	Kishoreganj	Nikli	1	S	16545
34879	Kishoreganj	Pakundia	1	S	14944
34892	Kishoreganj	Tarail	1	S	12380
35440	Madaripur	Kalkini	1	S	22370
35454	Madaripur	Madaripur	1	S	22620
35480	Madaripur	Rajoir	1	S	19824
35487	Madaripur	Sibchar	1	S	22265

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
35610	Manikganj	Daulatpur	1	S	17472
35622	Manikganj	Ghior	1	S	11593
35628	Manikganj	Harirampur	1	S	12847
35646	Manikganj	Manikganj	1	S	17897
35670	Manikganj	Saturia	1	S	11527
35678	Manikganj	Sibalay	1	S	13164
35682	Manikganj	Singair	1	S	17365
35924	Munshiganj	Gozaria	1	S	9257
35944	Munshiganj	Lohajang	1	S	7439
35956	Munshiganj	Munshiganj	1	S	10188
35974	Munshiganj	Serajdikhan	1	S	15144
35984	Munshiganj	Srinagar	1	S	14888
35994	Munshiganj	Tongibari	1	S	8245
36113	Mymensingh	Bhaluka	1	S	44014
36116	Mymensingh	Dhobaura	1	S	23010
36120	Mymensingh	Phulbaria	1	S	34554
36122	Mymensingh	Gafargaon	1	S	31961
36123	Mymensingh	Gouripur	1	S	22917
36124	Mymensingh	Haluaghat	1	S	31036
36131	Mymensingh	Ishwarganj	1	S	24207
36152	Mymensingh	Mymensingh	1	S	30252
36165	Mymensingh	Muktagachha	1	S	25261
36172	Mymensingh	Nandail	1	S	27147
36181	Mymensingh	Phulpur	1	S	46823
36194	Mymensingh	Trisal	1	S	28144
36702	Narayanganj	Araihazar	1	S	12833
36704	Narayanganj	Sonargaon	1	S	13624
36768	Narayanganj	Rupganj	1	S	15195
36852	Narsingdi	Manohardi	1	S	15139
36860	Narsingdi	Narsingdi	1	S	16695
36864	Narsingdi	Raipura	1	S	23830
36876	Narsingdi	Sibpur	1	S	16254
37204	Netrakona	Atpara	1	S	16098
37209	Netrakona	Barhatta	1	S	19369
37218	Netrakona	Durgapur	1	S	24210
37238	Netrakona	Khaliajuri	1	S	20351
37240	Netrakona	Kalmakanda	1	S	34694

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
37247	Netrakona	Kendua	1	S	24550
37256	Netrakona	Madan	1	S	19888
37263	Netrakona	Mohanganj	1	S	21311
37274	Netrakona	Netrakona	1	S	26582
37283	Netrakona	Purbadhala	1	S	25013
38207	Rajbari	Baliakandi	1	S	18588
38273	Rajbari	Pangsha	1	S	33265
38276	Rajbari	Rajbari	1	S	22250
38614	Shariatpur	Bhedarganj	1	S	17238
38625	Shariatpur	Damudya	1	S	7412
38636	Shariatpur	Goshairhat	1	S	13523
38665	Shariatpur	Naria	1	S	15479
38669	Shariatpur	Palong (Sadar)	1	S	11198
38694	Shariatpur	Janjira	1	S	17020
38967	Sherpur	Nakla	1	S	15431
39309	Tangail	Basail	1	S	13097
39319	Tangail	Bhuapur	1	S	16927
39323	Tangail	Delduar	1	S	14015
39338	Tangail	Gopalpur	1	S	17067
39347	Tangail	Kalihati	1	S	22790
39357	Tangail	Madhupur	1	S	42777
39366	Tangail	Mirzapur	1	S	30416
39376	Tangail	Nagarpur	1	S	19458
39385	Tangail	Shakhipur	1	S	40930
39395	Tangail	Tangail	1	S	23037
40114	Bagerhat	Chitalmari	1	S	14312
40138	Bagerhat	Kachua	1	S	8531
40156	Bagerhat	Mollahat	1	S	15929
41807	Chuadanga	Alamdanga	1	S	27628
41823	Chuadanga	Chuadanga	1	S	23128
41831	Chuadanga	Damurhuda	1	S	25984
41855	Chuadanga	Jibannagar	1	S	15899
44104	Jessore	Abhoynagar	1	S	16764
44109	Jessore	Bagherpara	1	S	18874
44111	Jessore	Chaugachha	1	S	22584
44123	Jessore	Jhikorgachha	1	S	24381
44138	Jessore	Keshabpur	1	S	18799

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
51095	Bogra	Sonatala	1	S	11152
53221	Gaibandha	Phulchhari	1	S	22673
53288	Gaibandha	Shaghata	1	S	18337
56403	Naogaon	Atrai	1	S	24325
56460	Naogaon	Naogaon	1	S	23660
56485	Naogaon	Raninagar	1	S	21975
56909	Nator	Bagatipara	1	S	11471
56915	Nator	Baraigram	1	S	25053
56941	Nator	Gurudashpur	1	S	16371
56944	Nator	Lalpur	1	S	26002
56963	Nator	Nator	1	S	31933
56991	Nator	Shingra	1	S	47730
57605	Pabna	Atgharia	1	S	14564
57616	Pabna	Bera	1	S	17301
57619	Pabna	Bhangura	1	S	10464
57622	Pabna	Chatmohar	1	S	25590
57633	Pabna	Faridpur	1	S	12357
57639	Pabna	Ishwardi	1	S	19822
57655	Pabna	Pabna	1	S	33706
57672	Pabna	Santhia	1	S	28048
57683	Pabna	Sujanagar	1	S	24725
58112	Rajshahi	Bagmara	1	S	28427
58182	Rajshahi	Puthia	1	S	15916
58811	Sirajganj	Belkuchi	1	S	10083
58844	Sirajganj	Kamarkhanda	1	S	7682
58850	Sirajganj	Kazipur	1	S	21130
58861	Sirajganj	Raiganj	1	S	21729
58867	Sirajganj	Shahzadpur	1	S	23227
58878	Sirajganj	Sirajganj	1	S	22676
58889	Sirajganj	Taras	1	S	26806
58894	Sirajganj	Ullapara	1	S	35104
63602	Habiganj	Ajmiriganj	1	S	15951
63611	Habiganj	Baniyachang	1	S	43255
63644	Habiganj	Habiganj	1	S	21965
63668	Habiganj	Lakhai	1	S	17113
63671	Habiganj	Madhabpur	1	S	25382
63677	Habiganj	Nabiganj	1	S	36185
69018	Sunamganj	Bishambarpur	1	S	17677

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
69023	Sunamganj	Chhatak	1	S	35029
69029	Sunamganj	Dirai	1	S	37281
69032	Sunamganj	Dharmapasha	1	S	39274
69033	Sunamganj	Dwarabazar	1	S	30131
69047	Sunamganj	Jagannathpur	1	S	32131
69050	Sunamganj	Jamalganj	1	S	28545
69086	Sunamganj	Sulla	1	S	22298
69089	Sunamganj	Sunamganj	1	S	52259
69092	Sunamganj	Tahirpur	1	S	22675
69108	Sylhet	Balaganj	1	S	31018
69120	Sylhet	Bishwanath	1	S	16767
69127	Sylhet	Companiganj	1	S	28564
69141	Sylhet	Gowainghat	1	S	44572
69162	Sylhet	Sylhet	1	S	36789
			273		5,707,710
10428	Barguna	Borguna	2	MS	25277
10485	Barguna	Patharghata	2	MS	19623
10921	Bhola	Burhanuddin	2	MS	18636
21578	Chittagong	Sandwip	2	MS	27387
21954	Comilla	Homna	2	MS	13751
22245	Cox's bazar	Kutubdia	2	MS	6510
36807	Narsingdi	Belabo	2	MS	9219
38229	Rajbari	Goalanda	2	MS	10200
40108	Bagerhat	Bagerhat	2	MS	17418
40160	Bagerhat	Morelganj	2	MS	33178
40177	Bagerhat	Sarankhola	2	MS	9966
46528	Narail	Kalia	2	MS	24890
51033	Bogra	Dhubchachia	2	MS	14344
52710	Dinajpur	Birampur	2	MS	18910
52747	Dinajpur	Hakimpur	2	MS	8958
53224	Gaibandha	Gaibandha	2	MS	27176
53847	Joypurhat	Joypurhat	2	MS	20723
53858	Joypurhat	Kalai	2	MS	14244
53861	Joypurhat	Khetlal	2	MS	13426
56447	Naogaon	Manda	2	MS	34635
58131	Rajshahi	Durgapur	2	MS	16210
58153	Rajshahi	Mohanpur	2	MS	13145

Geocode	District Name	Upazila Name	Boro Zone	Zone*	Cultivated Area (Ha)
65874	Moulvi bazar	Moulvi Bazar	2	MS	27179
			23		425,005
10409	Barguna	Amtali	3	LS	44170
21508	Chittagong	Banskhali	3	LS	26029
21537	Chittagong	Hathazari	3	LS	12517
21553	Chittagong	Mirsharai	3	LS	22710
21561	Chittagong	Patia	3	LS	11989
27521	Noakhali	Companiganj	3	LS	27289
36863	Narsingdi	Palas	3	LS	6423
39328	Tangail	Ghatail	3	LS	40940
44712	Khulna	Batiaghata	3	LS	17891
44740	Khulna	Dighalia (Daulathpur)	3	LS	4402
44769	Khulna	Phultala	3	LS	4798
51094	Bogra	Shibganj	3	LS	26490
52730	Dinajpur	Chirirbandar	3	LS	27606
52738	Dinajpur	Fulbari	3	LS	20705
53230	Gaibandha	Gobindaganj	3	LS	38365
53813	Joypurhat	Akkelpur	3	LS	12438
53874	Joypurhat	Panchbibi	3	LS	26149
54908	Kurigram	Rajibpur (Dhushmara)	3	LS	9178
58110	Rajshahi	Bagha	3	LS	13104
58125	Rajshahi	Charghat	3	LS	12694
58542	Rangpur	Kaunia	3	LS	12652
58592	Rangpur	Taraganj	3	LS	11496
58827	Sirajganj	Chauhali	3	LS	13087
63605	Habiganj	Bahubal	3	LS	22306
69153	Sylhet	Jaintapur	3	LS	17040
			25		482,468